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To the Graduate Council:

I am submitting herewith a thesis written by Paschal N. Strong, Jr. entitled "Activity and T-maze Performance of the White Rat as a Function of Drive and Apparatus." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Psychology.

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ACTIVITY AND T-MAZE PERFORMANCE OF THE WHITE RAT AS A FUNCTION OF DRIVE AND APPARATUS

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Doctor of Philosophy

by
Paschal NEILSON Strong, Jr.

June 1955

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TABLE OF CONTENTS

CHAPTER		PAGE
I.	THE BASIC PROBLEM	1
	Introduction	1
	The specific problem	3
II.	ACTIVITY OF THE WHITE RAT AS A FUNCTION OF FOOD DEPRIVATION	6
	Types of apparatus used	7
	Food deprivation and activity	12
	Experiment 1--part 1	15
	Experiment 1--part 2	20
	Results--parts 1 and 2	21
	Summary	32
III.	THE EFFECT OF HUNGER AND FORCING IN T-MAZE LEARNING	36
	Experiment 2	41
	Summary	72
IV.	THE RELATIONSHIP BETWEEN ACTIVITY AND MAZE PERFORMANCE	75
	Method	77
	Results	78
	Discussion	80
	Summary	82

CHAPTER PAGE

BIBLIOGRAPHY 84

APPENDICES 92

Appendix A--Individual rat activity data expressed in standard deviation units 93

Appendix B--Individual rat conditioning and extinction time measures 99

LIST OF TABLES

TABLE		PAGE
I.	Pre- and Post-Deprivation Mean Activity in S.D. Units for Contact and Microswitch Groups	24
II.	Sex Differences in Activity, All Groups Combined	26
III.	Number of Trials for Each Rat During Conditioning and Extinction	44
IV.	Average Errors per Trial in Conditioning and Extinction	47
V.	Average Latency per Trial During Conditioning and Extinction	52
VI.	Average Latency per Trial for Forced and Non-Forced Trials of the Forced Groups	53
VII.	Number of Animals at Each Deprivation Level Above and Below the Median Choice Time of that Level	58
VIII.	Number of Animals at Each Deprivation Level Above and Below the Median Total-Minus-Choice Time of that Level	61

TABLE PAGE

IX. Number of Failures to Make a Choice and Average Number per Trial of B-C Traversals 64

X. Rank Order Correlations Between Activity and Three Measures of Maze Performance 79

LIST OF FIGURES

FIGURE PAGE

1. Top and Side View of the Contact Stabilimeter Used in the Present Study 17
2. Pre-Deprivation and Post-Deprivation Activity of Each Group Expressed in Deviations from Its Own Pre-Deprivation Mean Activity 23
3. Relative Activity at Different Deprivation Levels for Different Types of Activity Apparatuses 33
4. Top View of the T-Maze Used in Experiment 2 42
5. Average Errors per Trial During Conditioning and Extinction 48
6. Average Latency per Trial in Seconds During Conditioning and Extinction. The Abscissa Represents Days of Conditioning and Extinction 50

7--a, b, c. Median Choice Time per Trial During Conditioning and Extinction 55

8--a, b, c. Median Total-Choice-Time per Trial During Conditioning and Extinction 60

CHAPTER I

THE BASIC PROBLEM

Introduction

In the usual psychological experiment certain operations are performed upon the organisms being studied and a certain portion of the total responses are measured. The operations performed upon the organism may be roughly divided into two classes, those which are systematically varied and define the various experimental groups, and those which are held constant across groups. Certain lawful relationships are then determined between those operations which are varied and the responses measured. Those operations which are held constant are considered to be factors which may also affect the responses being measured. It is usually felt that if these are held constant, then they will affect all groups equally and will not contaminate the results. The assumption here is that what is constant for the experimenter is constant for the various organisms. For example, in a T-maze problem, if the effect of several levels of hunger are being studied, the same maze is used with all groups, and it is assumed that the maze dimensions are constant for all groups. It may well be,

however, that a given maze dimension may differentially affect animals at different hunger levels. If, at each hunger level, we use two mazes of differing lengths and find that the results obtained from one maze are parallel to the results obtained from the other, then we may assume that a condition of constancy exists. In some cases it will be obvious that such a condition of constancy does exist in the experiment, but in others this condition should be tested before the inferences are generalizable.

It is to be noticed that the condition of constancy is defined by an a priori choice of the response of the organism to be measured. It may well be that if one does get results which appear to support a condition of constancy, it would not have been obtained had another response of the organism been measured. Therefore, one must use care in choosing which response of the organism he is going to measure.

In the experiments to be reported on in this paper, close attention was paid to the effect of certain of the operations which in previous experiments have been considered under the class of "constant operations." In the activity experiment, attention was focused on the effect of the apparatus used in measuring the activity, and in

the T-Maze experiment, attention was focused upon a certain training procedure that has been used in many learning experiments in the past.

The Specific Problem

Activity

Many investigations have been performed in which the activity of animals has been studied as a function of numerous variables, one of these being hunger. Although many different types of apparatuses have been used in the past, results, up until the last few years, have been fairly comparable. Now, however, a once clear area of agreement has become clouded and another of the "known" of psychology has become a "maybe." Since activity is a term covering a wide range, if not all, of the organism's responses, the type of activity being measured becomes of first importance and this is clearly a function of the apparatus used. In this experiment two types of apparatuses are used, one of fairly recent origin and the other especially designed for this study for reasons to be given in detail later. The other types of apparatuses have been used enough so that we may assess their effect on variables that have been measured. Thus we have a chance to determine the effect of hunger on activity as

a function of the apparatus used.

Forcing

In many T-maze experiments (to be discussed later in this paper) animals are often run several trials a day --some are free choice situations and some are forced choice situations. The reasons for employing such procedure are sometimes obvious, at other times obscure. Quite often animals are at different hunger or thirst levels and since this procedure is used uncritically the experimenters are obviously assuming the above discussed condition of constancy. In the present experiment the effect of the forcing procedure per se was determined over a wide range of hunger levels and on many measures of maze performance.

Activity and Maze Performance

Some experimenters have felt that general activity and maze performance should be related in some manner and a few experiments have been done to ascertain this relationship. (1, 33, 34, 36, 41, 49) Obviously, unless it is known what sort of activity is being measured, the relation of activity to maze performance will remain obscure. Equally obvious is the need to know the effect of the maze and running procedures upon the measures of maze performance being used in order to have some understanding

of the role of the particular activity being measured. Since the proposed experiments aim, in some small measure, to assess the type of activity measured and the effect of the maze procedures used, some idea of the relationship between these variables can be obtained.

CHAPTER II

ACTIVITY OF THE WHITE RAT AS A FUNCTION OF FOOD DEPRIVATION

Many studies have been done on the bodily activity of the white rat. Variables such as hunger, thirst, nutrition, somatic insult, environmental restriction, and others have been tested in order to see how they affect this activity. The reasons for studying this aspect of the white rat's behavior are seldom made explicit but four main reasons can be inferred.

1. The gross activity of an animal may be thought of as indicating, to some crude extent, the state of bodily disequilibrium and is thus important in homeostatically oriented theories. (8, 22, 44, 45)

2. It has been used as a criterion for naming and ordering so called "primary drives." (42, 49, 69)

3. Activity of an organism can be thought of as a measure of the amount of immediately available energy which can be channelized into a particular response (for example, maze running). (17, 36, 49)

4. Activity may be considered as an indication of the comparative excitatory value of various stimuli. (5, 48)

Whatever the reason for studying activity it is elementary to define what kind of activity is being measured. Activity as a concept is too broad and ambiguous to be of any value. Elementary as this sounds, it has apparently escaped the notice of most researchers in this field. If any modifiers at all are used with this term they are usually "Spontaneous," "Random," "Restless," "General," etc. Modifiers such as these do little but point out the investigator's inability to specify the source of this behavior and are useless in describing the behavior. Generalizations from such data become questionable.

The kind of activity being measured is completely dependent upon the apparatus used and it will therefore be instructive to examine the various types that have been employed and see what inferences can be made about the behavior being measured by these apparatuses.

Types of Apparatus Used

In studying the effect of hunger upon activity previous investigators have used at least six different types of apparatuses. A brief description of each follows:

The Activity Wheel

This apparatus consists of a hollow revolving drum of various diameters in which the animal runs. The number of revolutions is the usual measure of activity although kymographic and cumulative step recordings have also been used. This apparatus is the most popular device used to measure the activity of the rat. Skinner (55) gives an excellent discussion of the physics involved in this apparatus. It is obvious that this apparatus measures, almost exclusively, activity of a locomotory nature. It is also probable that in fairly free turning wheels there is a distinct possibility of positive apparatus feed back from the proprioceptive cues furnished by running plus the inertia of the wheel. In the light of recent experiments it is quite likely that this has a great effect on the activity measured. This apparatus has several important characteristics.

1. Many studies (13, 14, 26, 38) have shown that it takes from three to six weeks for animals to reach a base level of activity on these machines; that is, to adapt to them.

2. Hall (21) has shown that some animals can depart from their base levels by a factor of 5,000%.

3. Activity measured on this apparatus is usually an all or nothing affair; that is, it comes in bursts of

activity and over a twenty-four hour period tends to become cyclic in frequency.

Spring Mounted or Tambour Machines

The second most popular machine is the spring mounted or tambour machine. These machines have declined in popularity but many of the classic studies in activity have used them. (42, 44, 70) These machines appear to be capable of measuring both locomotory and non-locomotory behavior, depending on the sensitivity of the apparatus. The less sensitive the apparatus, the more gross the movement must be before it will register. The important characteristics of this type of apparatus are:

1. They almost always use kymographic recordings which give a record difficult to interpret. What is usually treated by the investigator as results are the number of arbitrary time units in which movement occurred (usually about five minutes). Thus animals can be vastly different in total energy expenditure and yet appear almost equally active.

2. This type of apparatus is very sensitive to differences in body weights of organisms being tested and since weight changes greatly in the early life of the rat it becomes a poor instrument on which to see

the effect of age changes and of any procedures that cause significant weight changes.

Pedometers

Liddell and others (22, 35) have used this instrument on sheep and dogs, their size making other devices impractical. Pedometers measure locomotory and some of the more gross non-locomotory movements but emphasize the locomotion of the organism. They are comparatively delicate, breaking easily, and are probably of little use for short periods of observation.

Field Measurements

Some investigators (41, 42, 50) have merely measured the amount of unit traversals in an open field or a maze for a given unit of time as an indication of activity. This is obviously a measurement of almost pure locomotion. It is also applicable to larger organisms. Some field studies have shown, however, that there is an adaptation period needed here before any base activity can be determined.

Electric Eye Devices

Recently Siegel (51, 53, 54) has described an ingenious apparatus for measuring movements in an animal's

cage. Activity is registered whenever the animal crosses the path of an electric eye. This apparatus also measures, to a great extent, locomotory behavior. This apparatus has the following characteristics (51):

1. Rapid adaptation.
2. High machine to machine comparability.
3. The animal is not removed from his living cage.

Tilt Mechanisms

Recently Campbell (4) has described an apparatus which consists essentially of a platform resting on four micro-switches and a center shaft. Movements around the cage will cause these switches to close and advance a counter. With certain modifications this apparatus is used in the present study. Like the tambour and spring mounted machines it has the ability to measure non-locomotory behavior as well as locomotory behavior, depending upon the sensitivity of the apparatus. This type of apparatus has the following characteristics:

1. Easily constructed.
2. Quantitative measures useful for short periods of observation.
3. Minimum disturbance of the animal's usual living environment.
4. Rapid adaptation.

Food Deprivation and Activity

Until quite recently almost all, if not all, investigators studying the effect of hunger upon activity of the white rat have reported large increases in activity up until 48-72 hours of food deprivation (13, 21, 44, 54). Richter (44) has demonstrated the relationship between the two hour cycle of activity in the rat and its stomach contractions and others have shown maximal activity prior to feeding when the rat has become accustomed to a regular feeding schedule. Some textbooks state, without qualification, that hungry animals are more "Restless" than non-hungry animals (7, 8, 22).

Recently, however, Sheffield and Campbell (5, 48) have done a series of experiments showing that hunger brings only slight increases in activity if there are no changes in external stimulation. Changes in the environment, however, do cause hungry and satiated animals to be significantly more active. This effect is greater for hungry than for non-hungry animals. Sheffield and Campbell state (48, p. 97):

> It is commonly assumed that hunger is a state that drives the hungry animal into restless "spontaneous" activity. Casual observation of hungry animals, however, gives a different picture of the effects of hunger on

activity: (a) Left to themselves, caged hungry rats appear to sleep much of the time and do not move about restlessly.

Sheffield and Campbell suggest that hunger has the effect of lowering the animal's thresholds to external stimulation so that they respond more actively to these stimuli.

In studying Sheffield's and Campbell's premise, one must then seek an explanation for the differences between their study and previous studies. In the case of the experiments using the activity wheel two explanations suggest themselves.

1. The external stimuli afforded by the wheel's turning. These would be mainly of an auditory and visual nature. Hall (21) still found an increase when he controlled for auditory cues.

2. Internal stimuli caused by the rotating of the wheel. These would be primarily proprioceptive in nature.

Both of these explanations fit well into the formulation of Sheffield. Studies that have used tambour or spring mounted devices are so difficult to interpret for reasons previously stated that they will not be scrutinized at present.

Some recent studies that are harder to handle with Sheffield's hypothesis are those of Siegel (51,54)

in which external stimuli seem better controlled and yet there was an immediate rise in activity with food deprivation. Possible sources could be the stimuli arising from other animals nearby, a factor controlled by Sheffield, or the stimulation from the electric eye itself, which is not likely since these beams are narrow and not very bright.

The present investigator suggests another hypothesis for the discrepancy--not in any way suggesting it as a substitute for Sheffield's hypothesis but as another important factor which must be considered. The hypothesis states that a great deal of the difference between the two studies lies in the type of activity being measured. That is, that Siegel's apparatus measures locomotion almost exclusively while Sheffield's probably measures both locomotory and non-locomotory activity. A recent article by Cotton (6) shows the importance of such a distinction. He found that in a runway maze hungry animals do not run faster than non-hungry animals but that they show fewer responses which would interfere with locomotion. Hunger then may act in one of three ways. It may cause a rise in locomotion, a fall in non-locomotion or both.

In order to test the feasibility of the above distinction, the present study was designed. The apparatus to be described was designed to measure, as much as possible, any movement of the animal. Also considered of importance was the minimizing of external changes when activity was being measured, getting a true baseline of activity before the animal has had any experience with food deprivation, and studying activity after the animal has experienced considerable food deprivation.

With the contact apparatus to be described in the first two parts of this study it was specifically predicted that hungry rats would show significantly less activity than they did when they were not hungry. With the microswitch apparatus used in the second part of the study, it was predicted that as in Sheffield's studies there would be a slight rise in activity with hunger.

Experiment 1--Part 1

Apparatus

The apparatus was designed to measure not only locomotory activity but also activity of a non-locomotory nature such as biting or chewing on the cage,

scratching, rearing, preening, etc. The apparatus (see Figure 1) consisted of a one-half inch thick plywood square, 10 inches on each side; dimensions identical with the bottom of the living cages. This platform is supported at the center of the bottom-side by a pointed steel shaft which fits into a conical depression. Below this platform is a square frame made from $1\frac{1}{4}$" x $1\frac{1}{4}$" stock, the inside dimensions being $10\frac{1}{2}$". At the middle of each side of the lower frame is a metal contact. About 1/8" below the square platform is another metal contact which extends far enough from the side to overlap the contact on the lower frame. Thus, when the platform is tilted, one or two of the sides will make contact with the plates, closing an electrical circuit and advancing an electro-magnetic counter. Obviously the opposite sides of the platform can not make contact simultaneously so that only two counters are needed for each activity recorder.

Subjects

The S's were 38 albino rats obtained from the Home Economics Department of the University of Tennessee. Twenty-four were female and 14 were male. These rats were obtained at weaning and, until the deprivation period, were maintained on an ad libitum diet of dry

Figure 1

Top and Side View of the Contact Stabilimeter Used in the Present Study

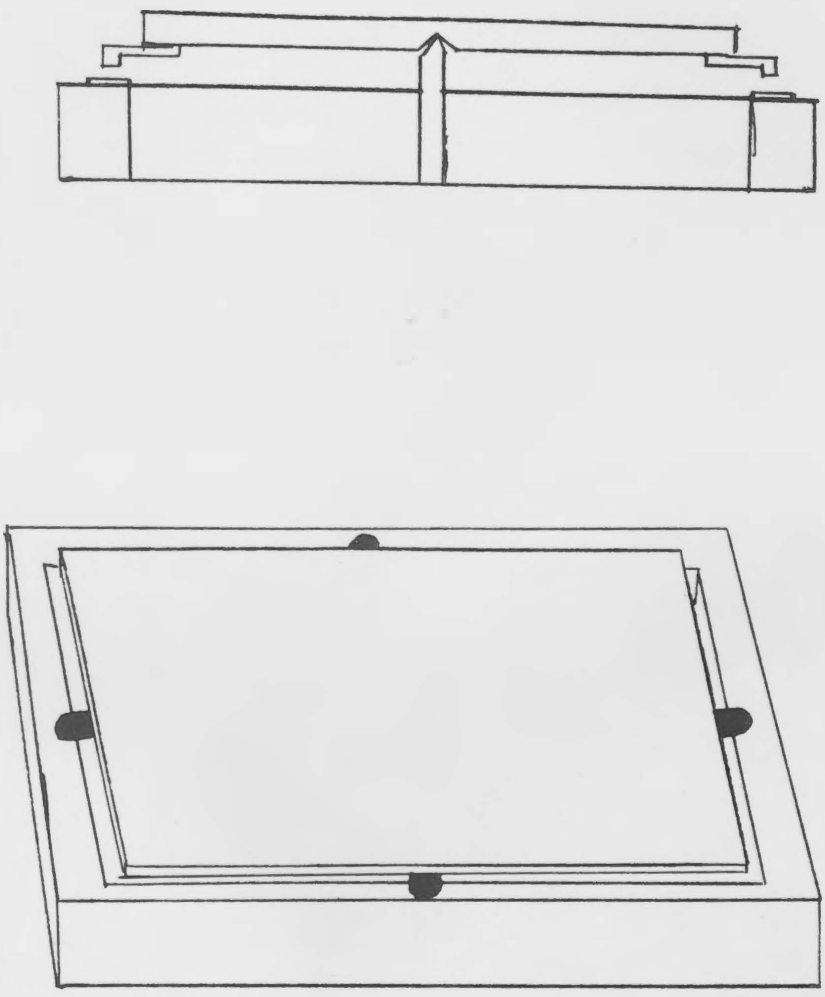


Fig. 1

Purina dog pellets and water.

Procedure

When the rats were between 120-160 days of age they were given twelve 30-minute trials on the activity recorders in order to determine their base activity level. These pre-deprivation trials were spaced over a period of 48 days. All animals were rotated on all four recorders so that each rat had three measurements on each recorder. The recorders were in the same room as the living cages but the counters were in another part of the building so that auditory stimulation at the time of measurements was kept at a minimum. Each animal's cage was placed on the recorder platform and readings were taken every five minutes for 30 minutes. The animal was not touched by E and remained in his living cage at all times. Food and water were in the cage during the measurements.

At the end of this pre-deprivation period the animals were divided into matched groups, based on individual rat activity, sex, and age. The distribution of sex is given in Appendix A. Originally only three groups of 10 rats were planned; these were the 0, 24, and 72 hour groups. Eight of the 72 hour animals died, however, after two weeks of this deprivation schedule so a fourth group, 48 hours hungry, was added. These animals were treated

exactly like the original groups except that they were not matched to the original group for pre-deprivation activity. As a group, these rats showed a slightly higher base activity than the original group; they were also slightly younger (90-160 days).

Each group was then placed on its respective deprivation schedule, with the 0 control group retaining food on an ad libitum basis. The 24 hour deprivation group was fed once every 24 hours on wet mash for a period of 30-45 minutes. This feeding always took place about 15 minutes after activity was measured. The 48 and 72 hour groups were also fed once every deprivation period for a similar length of time and their activity was also measured immediately before feeding. In both pre-deprivation and post-deprivation, activity was measured at approximately the same time in the evening. Illumination was kept constant for the entire length of this experiment. The 0 and 24 hour groups had 12 30-minute post-deprivation trials over a period of 30 days. The 72 hour group had at least five post-deprivation trials, the first four of which are included in the results. This was over a period of 12 days. The 48 hour group had 12 post-deprivation trials over a period of 45 days.

Experiment 1--Part 2

Apparatus

Two types of activity recorders were used. The first type was the same as in Part 1 of Experiment 1, except for minor improvements. The second type was similar to recorders used in Experiment 1, but with microswitches substituted for metal contacts. This was done for two reasons: (1) The wish to duplicate Sheffield's and Campbell's study to see if comparable results were obtained over a long period of time. (2) To have an apparatus that was proportionately less sensitive to non-locomotory activity than those used in Experiment 1. It was felt that microswitches would be less sensitive to non-locomotory activity since the switch must make a full upward excursion after being depressed in order to further advance the counters. Contact machines required only a slight upward excursion before the downward movement again registered a count. For comparable rats the microswitch machines gave only 20-30% as many impulses as the contact machines.

Subjects

The S's were 30 albino rats obtained from the same source as those in Experiment 1 and were treated identically. There were 15 males and 15 females

distributed evenly over drive groups. The exact distribution of sex is given in Appendix A. At an early age (40-60 days) the animals were matched for activity on the contact machines and were then divided into two groups also matched for age and sex. The group whose activity was measured on the contact machines, as in Part 1, will be called the contact group. The group whose activity was measured on the microswitch machines will be called the micro group. These two groups were run for 15 30-minute trials over a period of 23 days under satiation conditions. Each group was then divided into three subgroups of 0, 24, and 48 hours food deprivation matched for activity, sex, and age and were then run on post-deprivation trials in the same manner as Experiment 1. All animals were rotated across all machines. The 0 group had 12 post-deprivation trials over a period of 15 days, the 24 hour group had 9 post-deprivation trials over a period of 12 days, and the 48 hour group had 7 post-deprivation trials over a period of 12 days.

Results--Parts 1 and 2

At the end of the pre-deprivation phase of the various activity experiments the distribution of scores

on each counter of each machine was determined and the mean and standard deviation of each counter was computed. These distributions were somewhat positively skewed but close to a normal bell shaped curve. Each rat's daily score on a particular counter (two counters per machine) was divided by the standard deviation of that counter. In this way each rat could be compared to any other rat regardless of which machine they were on.

Figure 2 shows the pre-deprivation and post-deprivation activity of each deprivation group. The contact groups in Parts 1 and 2 had strikingly similar depression in post-deprivation activity for the respective deprivation groups and have therefore been combined. Each point represents three days of activity in order to smooth the curve. The plots express the deviation of each group from its pre-deprivation mean. Table I gives the means and standard deviation of each group for its pre- and post-deprivation periods. The one tail t value for each group was computed.

These values are in Table I and the probability of obtaining three independent probabilities of this magnitude was calculated according to Fisher (15).

A non-parametric analyses of variance was applied to the four contact groups before and after deprivation.

Figure 2

Pre-Deprivation and Post-Deprivation Activity of Each Group Expressed in S.D. Deviations from Its Own Pre-Deprivation Mean Activity

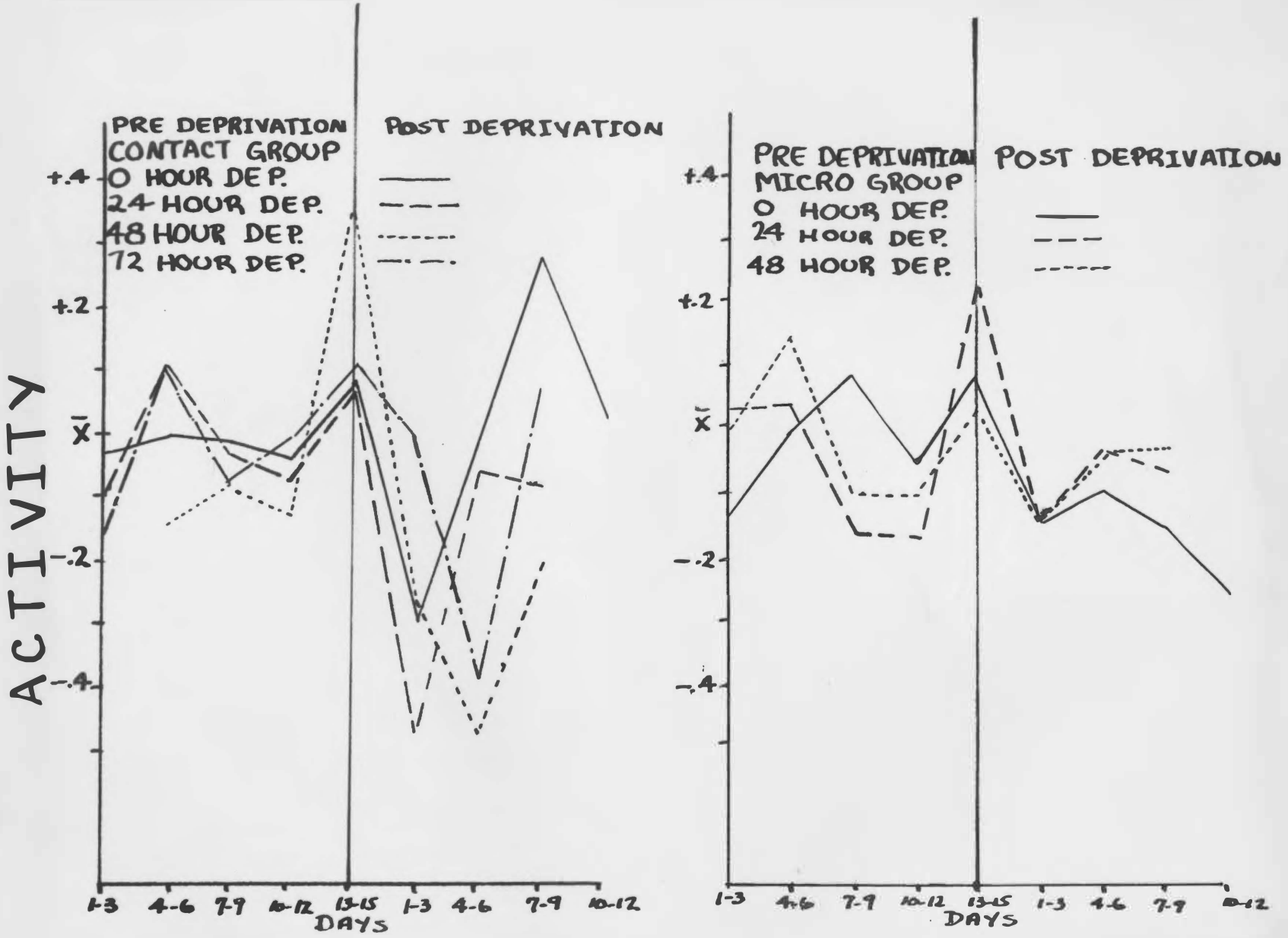

PRE DEPRIVATION
POST DEPRIVATION
CONTACT GROUP
0 HOUR DEP.
24 HOUR DEP.
48 HOUR DEP.
72 HOUR DEP.
+.4
+.2
X̄
-.2
-.4
ACTIVITY
1-3
4-6
7-9
10-12
13-15
DAYS
PRE DEPRIVATION
POST DEPRIVATION
MICRO GROUP
0 HOUR DEP.
24 HOUR DEP.
48 HOUR DEP.
+.4
+.2
X̄
-.2
-.4
1-3
4-6
7-9
10-12
13-15
DAYS

Fig. 2

TABLE I

PRE- AND POST-DEPRIVATION MEAN ACTIVITY IN S.D. UNITS
FOR CONTACT AND MICROSWITCH GROUPS

	Hours of Deprivation						
	Contact Group				Micro Group		
	0	24	48	72	0	24	48
N	15	15	15	10	5	5	5
Pre-Deprivation Mean	1.42	1.32	1.39	1.44	1.15	.96	1.01
Post-Deprivation Mean	1.42	1.16	1.09	1.28	1.00	.87	.95
Pre-Deprivation S.D.	.45	.42	.48	.45	.31	.33	.20
Post-Deprivation S.D.	.28	.36	.38	.45	.07	.16	.35
Pre-Post-Deprivation Rank Order Correlation	.60	.80	.42	.61	.90	.70	.80
t	0.00	2.39	2.50	1.33	1.36	.81	.60
p (one tail)		.015	.011	.11	.13	.22	.25
P of P's X^2			22.08				
P of P's			.001				

The X^2_H (three D.F.) for the differences between groups before deprivation was 0.27, and for differences after deprivation was 5.47. This latter value has a p of approximately .07. Because the groups were matched for activity this probability value is probably too large but a matched groups analysis of variance could not be used because the rats were not matched on a rat to rat basis. The pre-deprivation and post-deprivation X^2_H for the micro group are 1.36 and .55 respectively, both values being well within chance limits.

Since many studies have indicated that females are more active than males, this comparison was also made in order to see if this is a factor specific to certain types of activity or whether it is a general difference over a wide range of activity. Table II gives the means and standard deviations for females and males respectively. The t for these values is also given in Table II. It can be seen that females are significantly more active than males and that this seems to be true regardless of the apparatus used. Hitchcock, using an activity wheel, found that females were 56% more active than males. The difference is greater than that found in the present investigation (27%).

TABLE II

SEX DIFFERENCES IN ACTIVITY,
ALL GROUPS COMBINED

	Males	Females	t
N	29	41	
Mean Activity	1.14	1.45	
S.D.	.40	.57	3.20
$S.D._{mean}$	.073	.089	p .01

Contact Apparatus

Comparing all deprivation groups against the control group the results were in the direction predicted and highly significant. All deprivation groups considered separately were significantly less active at the .05 point except the 72 hour group. The data suggests that the maximum decrement occurs around 48 hours of hunger and then falls somewhat. The reliability of these machines as determined by the rank order correlation of each group between its pre-deprivation to post-deprivation is indicated in Table I along with those of the microswitch groups. It is significant to see that the reliability is as good across deprivation levels as within, suggesting that the effect of the deprivation is fairly constant between animals (i.e. groups changing drive level are as reliable as groupshaving no change in drive).

Microswitch Apparatus

The trends obtained with this apparatus were similar to those of Sheffield's with this exception: all groups showed a decrease in the post-deprivation period. Since post-deprivation activity was measured over a much longer period than in Sheffield's study this may be a factor of age. However, the groups

order themselves in the same way as Sheffield's 24 hour controls. The present differences are not significant but neither were Sheffield's over a short period of time.

It is of interest to note that over the three months period of the contact group's measurement there was no indication of a decrease in activity, suggesting that this type of activity does not show as great or rapid a decrement as the animal grows older.

Discussion

It was previously stated that until Sheffield's work most of the workers in this field were convinced that hungry rats were more active than non-hungry rats. However a close look at the experiments of that time would indicate many points that suggest that the relationship was not that clear cut. Although Richter did show an increase in activity with hunger and correlated this with the two hour cycles of stomach contraction in the rat, he also found that rats which were deprived of food and water showed an immediate and continuing decrease in activity. Unless it can be shown that under these conditions stomach contractions cease, the correlation would appear to be spurious or coincidental. This would also tend to throw serious doubt on any

homeostatically oriented theory since it is obvious that a rat both hungry and thirsty is in a greater state of disequilibrium than if just hungry or just thirsty. Hitchcock's studies (24) also cast doubt on the role of stomach contractions. In studying the effect of protein hunger and absolute hunger on activity, he found that both increased activity but that the protein hungry rats showed even more activity than the rats which had had nothing to eat. Thus the lack of food in the stomach per se would not seem to be the important factor.

Other experiments indicate that the use of such terms as "Spontaneous" activity indicates that this activity appears immediately as the rat gets hungry and are ignoring the indications that the activity, as usually measured, shows a significant increase over time even if the deprivation is held constant. Hall (21) showed that rats 23 hours hungry show a steady increase for 15 to 20 days in activity in a revolving drum apparatus until the activity was 1,438% that of the animal's mean base level. Sheffield and Campbell (48) also showed that if hungry rats get a signal before they are going to be fed they will show steadily increasing activity over a period of at least twelve days but that the signal, if not followed by food, will

cause the activity to slowly fall. Geir (16) ran two groups of rats which were 23 hours hungry for four one minute trials a day. One group was fed after each trial, the other was not. He found that the fed group yielded higher activity than the non-fed group and also found that the fed group continued to increase their activity for six to eight days. Reversing the groups, he found a switch in activity indicating that reinforcement of the activity is of great importance and that the activity will show extinction like any other learned response when the reinforcement is removed. Finger (13, 14) speaks of a satiation syndrome, by which he means that after an animal has been deprived, he shows more activity in an activity wheel but when food is restored ad libitum there is a drop in activity far below the animal's base level before the initial deprivation. For animals 24 hours hungry, this drop only lasted for the first day, but for hungrier animals it could last for two or three days. Since the drop comes so quickly it would seem to be due not to the fact that equilibrium is restored but to the generalization decrement incurred by such a radical change in what might be considered a conditioning situation. Richter and Wang (45) found rats would run from 0 to 27 miles a day. These high values

suggest that the running in the wheel may be self reinforcing since rats in their cages show no running to this extent.

Since neither the disequilibrium hypothesis nor stomach contraction explanations seem to be generally applicable, another explanation must be sought both to explain the results of previous investigations and the present results. If one orders the various types of apparatuses previously described by their emphasis on locomotion they would rank as follows:

1. Activity wheels which force the animal to run once he begins running in order to maintain his balance and produces large amounts of proprioceptive feedback.

2. Siegel's electric eye apparatus which only registers if the animal passes through the beam. There is no apparent feedback in this apparatus.

3. The stabilimeter which, depending on its sensitivity, can measure gross non-locomotory behavior as well as locomotion from one quadrant to another.

4. The apparatus used in this study, which is essentially a very sensitive stabilimeter.

If one then draws a family of curves indicating activity over various levels of deprivation for each

machine, one sees (Figure 3) that activity as a function of deprivation also orders itself in the same manner. Since Cotton has showed the value of distinguishing between locomotory and non-locomotory behavior in analyzing runway speed as a function of deprivation, it might be useful to see if such a formulation will work in this instance.

If we conceive of hunger as causing non-locomotion to decrease and drop out as a method of conserving bodily resources and, at the same time, increasing locomotion, which would serve as a method of finding food and of easing the hunger, the above ordering makes sense. This would also explain why, in this experiment, the decrement in activity seems to reach a maximum at 48 hours since by this time it is quite likely that non-locomotory activity had dropped to a low level while locomotion is still increasing. This hypothesis would in no way invalidate Sheffield's hypothesis but merely impresses upon any theorist in this field the necessity of clearly specifying the type of activity being measured.

Summary

Two types of stabilimeters were used. One was designed to be more sensitive to minor movements than the other.

Figure 3

Relative Activity at Different Deprivation Levels for Different Types of Activity Apparatuses

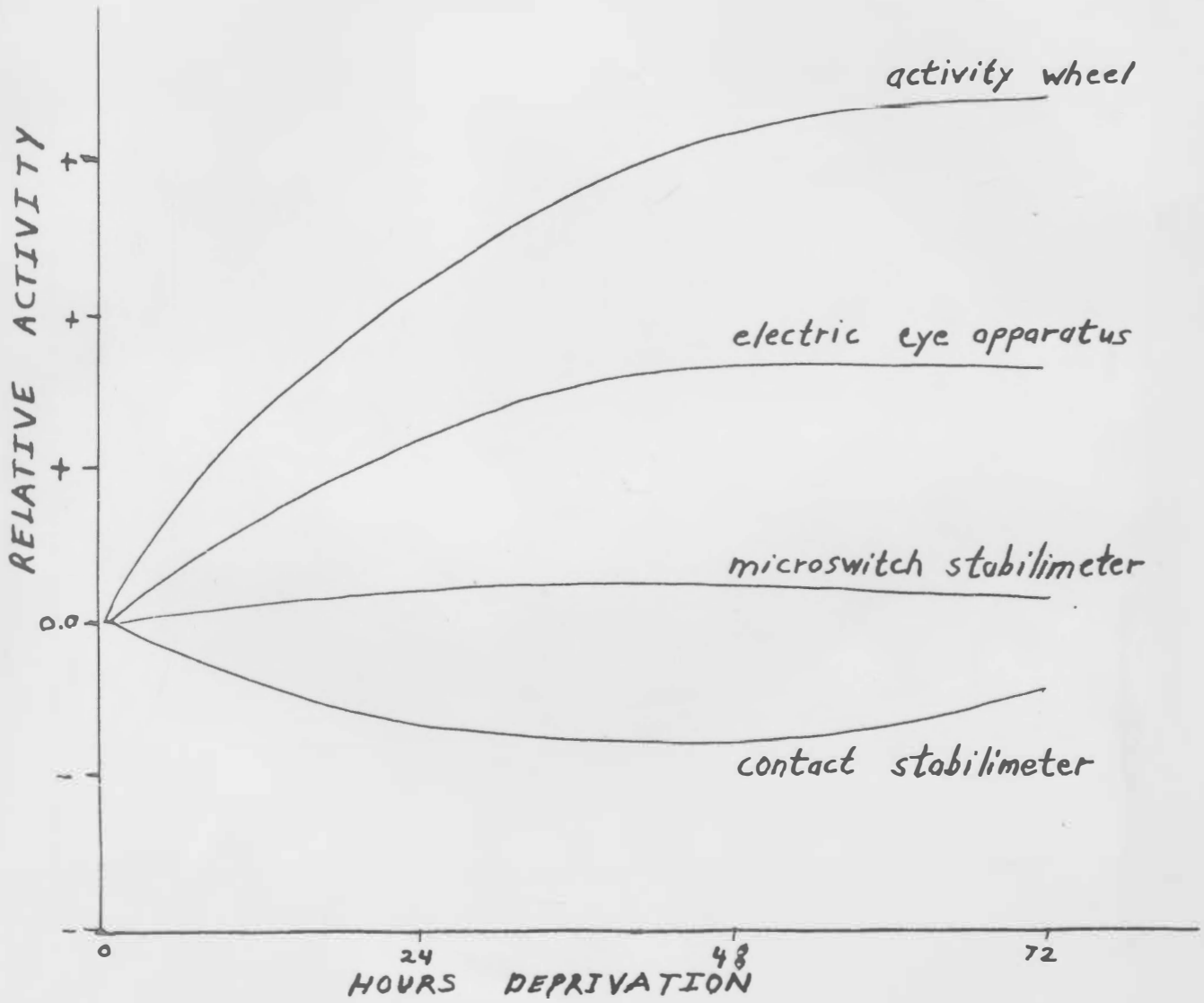

activity wheel
electric eye apparatus
microswitch stabilimeter
contact stabilimeter
RELATIVE ACTIVITY
0.0
0
24
48
72
HOURS DEPRIVATION

Fig. 3

S's were 70 albino rats, male and female. Animals were obtained at weaning and kept on an ad libitum diet for three to six months. During this period a series of measurements were taken in order to determine base level of activity. Animals were then matched for age, sex, and activity and split into four groups. One group, the control, remained on an ad libitum diet and the other three were put on 24, 48, and 72 hour deprivation schedules respectively. Activity measurements were again taken over a long period of time while the animals were on their respective deprivation schedule. Pre- and post-deprivation trials were one-half hour long with readings taken every five minutes.

On the sensitive machines, called contact machines, the deprived animals showed a significant drop in activity, with the 48 hour group showing the greatest decrement and the 72 and 24 hour groups the least.

On the less sensitive machines, called microswitch machines, all animals showed a drop in activity during the post-deprivation period but the control group showed the greatest decrement and the 48 hour group showed the least.

Females were found to be significantly more active than males by a factor of 20-30%.

The data were interpreted as showing that two kinds of activity operate in this situation, locomotory and non-locomotory. Locomotory activity seems to rise with deprivation and non-locomotory activity appears to drop out in deprived animals.

CHAPTER III

THE EFFECT OF HUNGER AND FORCING IN T-MAZE LEARNING

In a variety of T-maze learning situations, investigators have wished to control the number of times an animal may go to either side. Usually this is done by running the animal a given number of trials a day and on certain trials dropping a door at one side of the choice point so that the rat may only go in one direction. Four types of experiments have used this technique.

1. The great majority of experiments using this technique are those in which the investigator is trying to study the phenomenon of latent or incidental learning. This has been done in four ways.

a. An animal is motivated for a given reward (usually food or water) which is on one side of the maze. On the other side is an irrelevant reward to which, for a certain number of trials a day, he is forced. Later in the experiment the motivation of the animal is now changed so that the irrelevant reward becomes relevant and the animal's choice on the first free trial is considered to be an indication of latent learning (19, 27, 28, 60, 61).

b. This design, used more often (18, 30, 32, 64, 67) is like the first type except that the reward for which the animal is initially rewarded is on both sides and the irrelevant reward is on one side. As in the first, in a later phase of the experiment the motivation is changed so that the irrelevant reward becomes relevant.

c. This design (28, 37, 60) also commonly used has one reward on one side and a different reward on the other (usually food and water). The animal is run satiated for both and so forced that each day he goes to each an equal number of times. Later on in the experiment the animal is motivated for one or the other substance and his first free choice is again used as an indication of latent learning.

d. The animal is motivated by thirst but gets no water on either side of the maze. On one side is food, for which he is not motivated. As usual he is forced to each side of the maze equally. Later he is made hungry and his first free choice hungry is considered the test of incidental learning (40).

2. Denny and others (9, 10, 11) have used this method of forcing in order to assess the role of the incorrect response in a T-maze situation. By varying the

differences between the correct and incorrect end boxes and using forcing to keep exposure to the incorrect goal box constant between groups, Denny hoped to assess the secondary reinforcement value of the respective end-boxes.

3. Siegel (52) used forcing in a T-maze as a method of assuring equal exposure to each side in a T-maze while investigating the effect of differing amounts of initial response strengths in the situation. Here animals were rewarded on both sides, one group a few times and one group a great many times. After this has been done, a usual T-maze learning situation was used with one side arbitrarily designated correct for each rat.

4. Teel and Webb (65, 66) for some unnamed reason used forcing in a T-maze experiment in which, from the first, one side was designated for the rat as correct and the usual learning and extinction procedure was followed. Since they were studying the effect of deprivation on this type of learning it is likely that they wished to give all groups an equal number of reinforcements.

A few of these investigators (30, 67) have questioned the effect of the forcing procedure and have run

controls to see what, if any, effect it has. Unfortunately they have used only errors in the maze as a criterion and usually at only one deprivation level. Kendler, however, made the following observation (29, p. 269):

> An examination of the running times on the last day of the training series (seventh day) reveals a marked difference between the free choice and the force choice trials. The thirsty animals averaged 4.8 seconds on their free choice trials (all correct) and 78.6 seconds on their forced trials (all to food). This was significant at the .01 level. The hungry animals had a mean running time of 6.3 seconds on their free choice trials (all correct and to food) as compared with a mean running time of 9.9 seconds on their forced trials (all to water). This was significant at the .05 level.

Kendler also states that this was not because they ran slower but because they kept trying to go to the correct side on the forced trial. This certainly suggests that forcing may have a great effect upon the animal and that this effect may well be differential according to how strong the motivation to go to the side away from which the animal is being forced. Studies using only errors as a criterion have found no differences between forced and non-forced animals.

The present investigation is designed to test the effect of forcing animals to go away from a goal for which they are motivated. Three levels of motivation are used from low to high and three main types of measures

have been used to describe the animal's behavior in the maze situation. These are:

1. Errors in conditioning and extinction.

2. Time scores in conditioning and extinction.

3. Behavioral protocols in conditioning and extinction.

The general hypotheses being tested are as follows:

1. Forcing will not in any way help learning.

2. In certain measures, most likely time and behavioral measures, forcing will have a deleterious effect.

3. This effect will be differential according to the motivational level of the animal. The higher the drive the greater the decrement.

4. This deleterious effect will be greatest at or near the choice portion of the maze.

It is hoped that such a study will indicate under which conditions forcing can and cannot be used without seriously affecting the results and generality of various studies.

Experiment 2

Apparatus

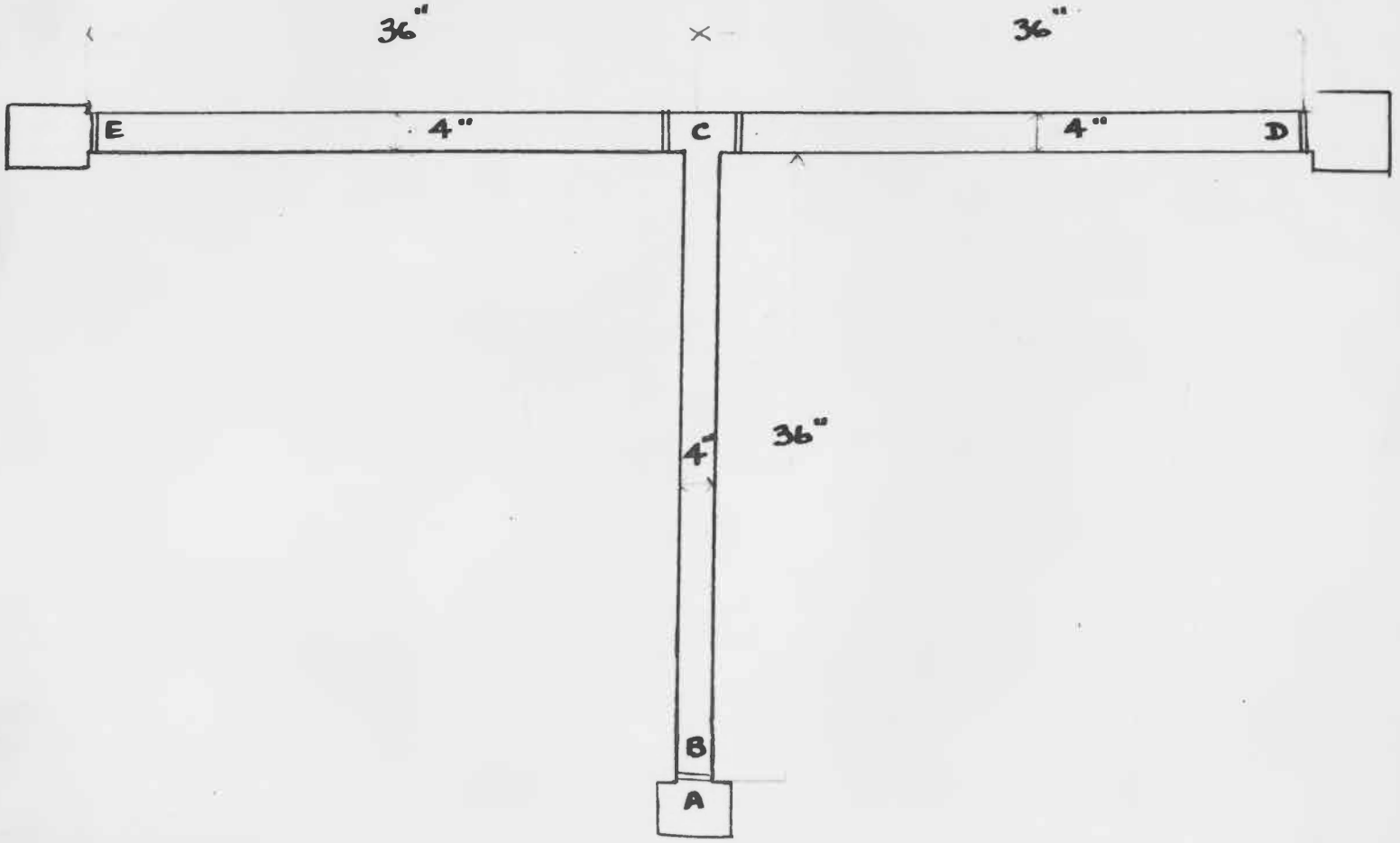
Figure 4 shows the construction and measurements of the T-maze. Guillotine doors are at B, C, D, and E. Electric timers, accurate to 1/100 of a second, were used to measure latency and choice time, and a stop watch was used to measure total running time. The doors, dropped by hand, were so wired that latency and time to make a choice were measured automatically by the action of the doors dropping.

Subjects

The S's were the same animals used in Part 2 of Experiment 1. They were 120-150 days old at the beginning of the experiment. They were maintained on their respective deprivation schedules and those rats used on the contact machine were the forced group while those used on the microswitch machines were the non-forced group. It will be recalled that these groups were previously matched for age, sex, and activity. At the beginning of the experiment all animals were given two free choice trials with no food in order to see if there was a strong position habit. If the animal turned in the same direction during these two trials, the other

Figure 4

Top View of the T-Maze Used
in Experiment 2


36"
36"
E
4"
C
4"
D
4"
36"
B
A

side was designated the correct side; otherwise, the animal's "correct side" was that opposite his first choice.

Procedure

1. Forced group. Conditioning. Animals in the forced group were run four trials a day with an inter-trial period of one to 10 minutes. The first two trials were free choice and if the rat turned in the same direction for both trials, the last two trials were forced in the opposite direction. This was done by dropping one of the doors at C (see Figure 4). If the animal alternated his choice on the first two trials, the third trial was also a free choice and the fourth trial was then forced so that the animal was run to the right side twice and to the left twice. The animals were reinforced for a correct choice with wet mash and allowed to eat for approximately 20 seconds. If the animal made a wrong choice, he was allowed to remain in the end box for a similar length of time. Besides the time measurements mentioned, errors, and number of stem traversals between B and C were also measured. Table III gives the number of reinforcements for each rat of the forced and non-forced groups.

TABLE III

NUMBER OF TRIALS FOR EACH RAT DURING CONDITIONING AND EXTINCTION

Group	Rat#	#Trials Cond.	# Reinforcements	#Trials Extinct.
0 hr. Dep. Forced	3	56	10	20
	4	56	22	20
	20	56	26	20
	26	56	18	20
	29	56	28	20
0 hr. Dep. Non-Forced	2	28	10	20
	9	28	3	20
	17	28	15	20
	27	28	6	20
	30	28	21	20
24 hr. Dep. Forced	6	48	24	20
	14	48	24	20
	19	48	24	20
	22	48	24	20
	28	48	24	20
24 hr. Dep. Non-Forced	10	24	23	20
	11	24	21	20
	12	24	22	20
	15	24	19	18
	23	24	15	died
48 hr. Dep. Forced	5	48	24	20
	7	48	24	20
	13	48	24	12
	24	48	24	20
48 hr. Dep. Non-Forced	1	24	22	20
	8	24	21	20
	16	24	22	20
	21	24	21	20
	25	24	21	20

2. Non-forced group. Conditioning. The non-forced group received two trials per day, both of them free choice trials. In all other respects they were treated as the forced group. If an animal failed to make a choice in 10 minutes, he was removed from the maze and recorded as "DNC" (did not choose). If he made a choice in less than 10 minutes but did not enter an end box within that time, the choice time was recorded and he was removed from the maze.

Extinction

Extinction was the same for both groups. All animals were given four unreinforced trials a day for five days. Total number of trials in extinction per rat are indicated in Table III. The same measures were taken as in conditioning and except for the lack of reinforcement and the fact that the non-forced group were run four trials a day, all conditions were the same. Rats were always fed about 15 minutes after their last trial. Animals were run at the same time in the evening and the usual light and sound conditions were present.

Results

1. Errors. For the forced group, errors are only counted when they occur on a free choice trial.

An error is counted when an animal turns into the wrong ally for a distance of one body length. At this point a door is dropped so that the animal cannot retrace.

Table IV gives the average error for each rat during conditioning and extinction.

Figure 5 shows the distribution over days of errors for the forced and non-forced groups at each deprivation level. Looking at the zero deprivation groups, it can be seen that the forced group varies right around a chance level of errors during conditioning with three days above chance, four days at chance, and seven days below chance. If we split those days exactly at chance so that half are above and half below, we find for the 14 days of conditioning that the forced group was above chance five times and below chance nine times. Expanding $(p +/q)^{14}$ we find that the probability of such an occurrence is approximately .44, a value too large to reject a chance hypothesis. The non-forced 0 deprivation group, on the other hand, is consistently above chance after the first two days of conditioning. Expanding the same binomial we see that the probability of such an occurrence is approximately .006, a small enough value to reject a chance hypothesis with a high degree of confidence. The average error difference

TABLE IV

AVERAGE ERRORS PER TRIAL IN CONDITIONING AND EXTINCTION

Group	Rat Number	Conditioning	Extinction
0 hr. Dep. Forced	3	.43	.20
	4	.53	.44
	20	.25	.40
	26	.45	.33
	29	.68	.45
Group Mean		.47	.36
0 hr. Dep. Non-Forced	2	.65	.55
	9	.90	.85
	17	.72	.55
	27	.78	.50
	30	.25	.65
Group Mean		.66	.62
24 hr. Dep. Forced	6	.18	.30
	14	.08	.35
	19	.04	.25
	22	.12	.50
	28	.28	.40
Group Mean		.14	.36
24 hr. Dep. Non-Forced	10	.08	.35
	11	.04	.25
	12	.13	.50
	15	.21	.52
	23	.38	died
Group Mean		.17	.47
48 hr. Dep. Forced	5	.04	.47
	7	.15	.30
	13	.08	.33
	24	.11	.45
Group Mean		.10	.39
48 hr. Dep. Non-Forced	1	.08	.40
	8	.13	.35
	16	.08	.55
	21	.13	.30
	25	.13	.55
Group Mean		.11	.43

Figure 5

Average Errors Per Trial During
Conditioning and Extinction

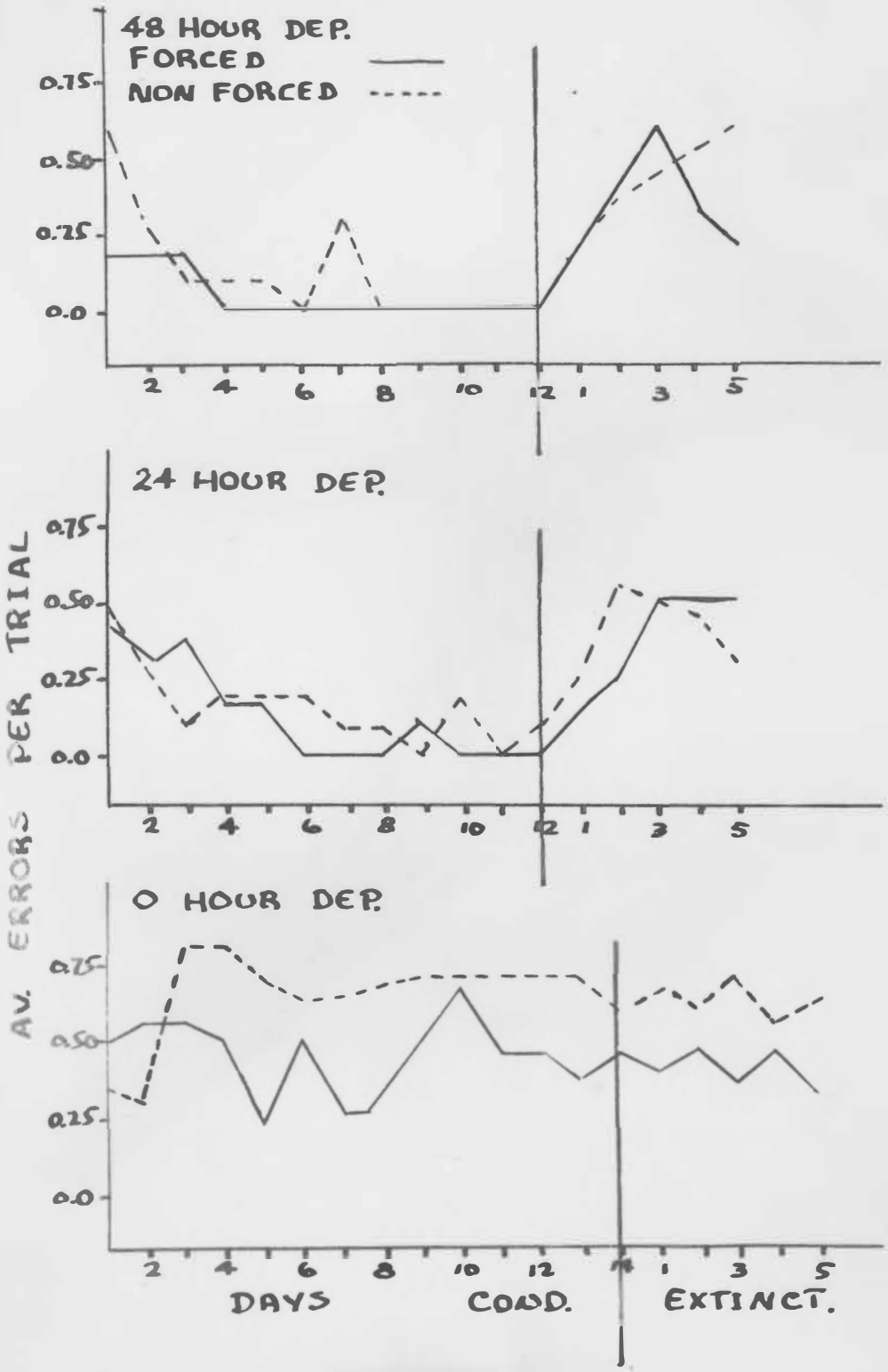

48 HOUR DEP.
FORCED
NON FORCED
0.75
0.50
0.25
0.0
2 4 6 8 10 12 1 3 5
24 HOUR DEP.
0.75
0.50
0.25
0.0
2 4 6 8 10 12 1 3 5
AV. ERRORS PER TRIAL
0 HOUR DEP.
0.75
0.50
0.25
0.0
2 4 6 8 10 12 1 3 5
DAYS
COND.
EXTINCT.

Fig. 5

between the two groups using Wilcoxon's non-parametric test for unpaired replicates (71) is not significant at the .05 level.

During extinction the forced zero deprivation group remains below chance for each of the five days and the extinction average of each rat is below chance. The non-forced zero deprivation group, on the other hand, continues to remain above chance and each rat's extinction average is above chance. Comparing the two groups during extinction using Wilcoxon's non-parametric test for unpaired replicates (71) shows this difference is significant below the .02 level.

There are no significant differences between the errors of the forced and non-forced group during conditioning and extinction at the 24 or 48 hour deprivation level although the forced group tends to have slightly fewer errors. Combining the 24 and 48 hour groups and testing for a significant difference between the forced and non-forced groups fails to yield significance at the .05 level.

2. Time measures.

a. Latency. Figure 6 shows the latencies of each group during conditioning and extinction. In order to test for trends early and late in conditioning, comparisons between groups were done for the first and

Figure 6

Average Latency Per Trial in Seconds During Conditioning and Extinction. The Abscissa Represents Days of Conditioning and Extinction

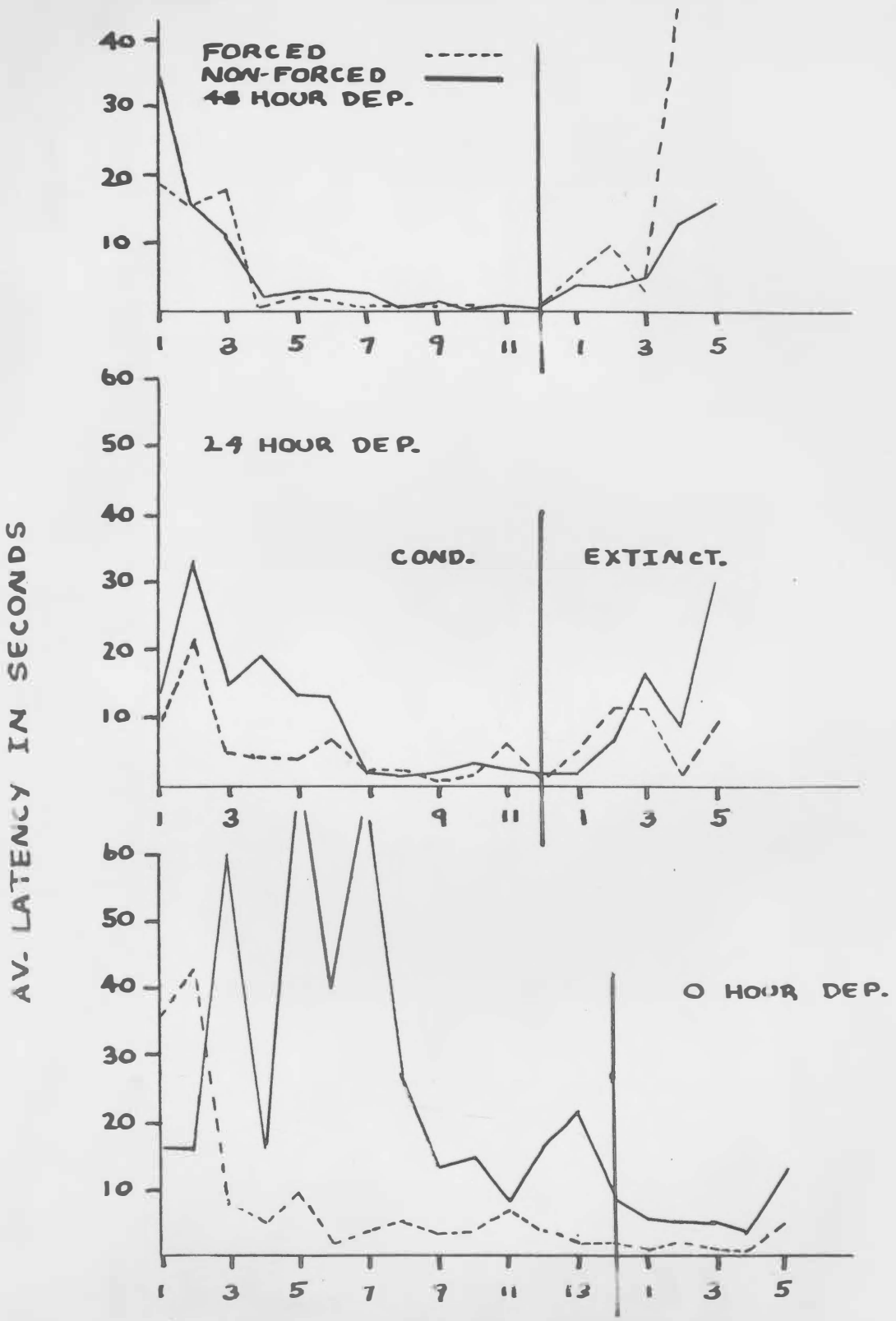

AV. LATENCY IN SECONDS
FORCED
NON-FORCED
48 HOUR DEP.
24 HOUR DEP.
COND.
EXTINCT.
0 HOUR DEP.

Fig. 6

second half of conditioning as well as extinction. Two types of comparisons were used. First, at each deprivation level the non-forced group is compared against the non-forced trials of the forced group (trials one and two for the forced groups). Secondly, within the forced groups trials one and two are compared against trials three and four.

From Figure 6 it can be seen that the zero deprived non-forced group has, for every day except the first two days of conditioning, a considerably higher average latency than the zero deprived forced group. The latency of this group also varies over a considerably wider range. Comparing the forced to the non-forced group during the first half of conditioning (Table V) shows this difference has a probability of approximately .12 using the Wilcoxon non-parametric test. During the second half of conditioning this difference is significant at the .02 level. Comparing trials one and two against trials three and four of the zero deprived forced group (Table VI) we find no significant difference for the first half of conditioning but during the second half of conditioning the forced trials have significantly higher latencies (below the .05 point using the usual t for correlated means.

During extinction there is also a significant difference ($P = .05$) between the zero deprived forced

TABLE V

AVERAGE LATENCY PER TRIAL DURING CONDITIONING AND EXTINCTION

Group	Rat No.	Av.Latency 1st ½ Cond.	Av.Latency 2nd ½ Cond.	Av.Latency Extinction
0 hr. Dep. Forced	3	5.86	4.11	1.11
	4	15.26	6.76	3.98
	20	11.74	4.69	3.12
	26	42.93	1.46	1.09
	29	3.93	2.36	1.32
Group Mean		15.94	3.88	2.12
0 hr. Dep. Non-Forced	2	5.89	4.04	1.78
	9	113.90	46.96	5.40
	17	37.30	18.47	12.46
	27	40.42	48.81	9.87
	30	9.48	5.76	6.13
Group Mean		41.40	24.81	7.13
24 hr. Dep. Forced	6	6.47	2.05	10.25
	14	9.53	1.49	7.54
	19	4.04	5.34	13.29
	22	19.64	2.12	5.08
	28	2.72	6.74	1.71
Group Mean		8.49	2.55	7.57
24 hr. Dep. Non-Forced	10	53.58	3.75	24.72
	11	3.52	.63	1.80
	12	4.41	1.08	4.55
	15	18.98	3.53	4.03
	23	4.85	1.92	died
Group Mean		17.07	2.18	8.78
48 hr. Dep. Forced	5	23.30	1.02	37.60
	7	9.26	0.62	54.61
	13	4.01	0.94	6.85
	24	3.37	0.90	4.20
Group Mean		9.98	0.90	25.82
48 hr. Dep. Non-Forced	1	40.95	2.36	10.98
	8	5.01	0.53	1.18
	16	8.24	1.79	22.83
	21	3.20	0.84	1.95
	25	4.87	1.02	6.39
Group Mean		12.45	1.31	8.67

TABLE VI

AVERAGE LATENCY PER TRIAL FOR FORCED AND NON-FORCED TRIALS OF THE FORCED GROUPS

Group	Rat No.	First ½ Cond. Non-Forced Trials 1-2	First ½ Cond. Forced Ts.3-4	Second ½ Cond. Non-Forced Trials 1-2	Second ½ Cond. Forced Ts.3-4
0 hr. Dep.	3	6.94	4.78	3.87	4.69
Forced	4	8.76	21.76	4.89	9.29
	20	12.66	10.79	3.17	6.21
	26	29.36	56.54	1.36	1.55
	29	3.80	4.05	1.78	2.94
Group Mean		12.30	19.58	3.01	4.94
24 hr. Dep.	6	8.24	8.58	2.49	1.62
Forced	14	13.09	5.97	1.38	1.60
	19	4.18	4.14	1.79	8.88
	22	18.10	21.18	2.03	2.20
	28	3.98	1.59	0.82	0.67
Group Mean		9.52	8.29	1.70	2.99
48 hr. Dep.	5	23.61	22.99	0.77	1.29
Forced	7	9.63	8.88	0.54	0.71
	13	4.31	3.71	1.07	0.99
	24	2.79	4.08	0.54	1.35
Group Mean		10.08	9.92	0.73	1.08

and non-forced groups.

For the 24 and 48 hour deprivation levels, there are no significant differences between the forced and non-forced groups and no significant differences within the forced group between trials one and two (the free choice trials) and trials three and four (the forced trials) during either half of conditioning.

There are no significant differences between the 24 or 48 hour forced and non-forced groups during extinction. During the last two days of extinction of the 48 hour group one rat died so that the sample number was reduced by 25%.

b. Choice time. Choice time is defined as the amount of time required for the rat to go from B (see Figure 4) to C and make a choice. Latency is not part of this measure. Figure 7--a, b, c, shows the choice times at each deprivation level for the non-forced group, for trials one and two for the forced groups, and trials three and four for the forced group. Three comparisons are made. Trials one and two of the forced group against the two trials of the non-forced group, trials three and four of the forced group against the non-forced group, and trials one and two of the forced group against trials three and four of the forced group.

Figure 7--a, b, c

Median Choice Time per Trial During
Conditioning and Extinction

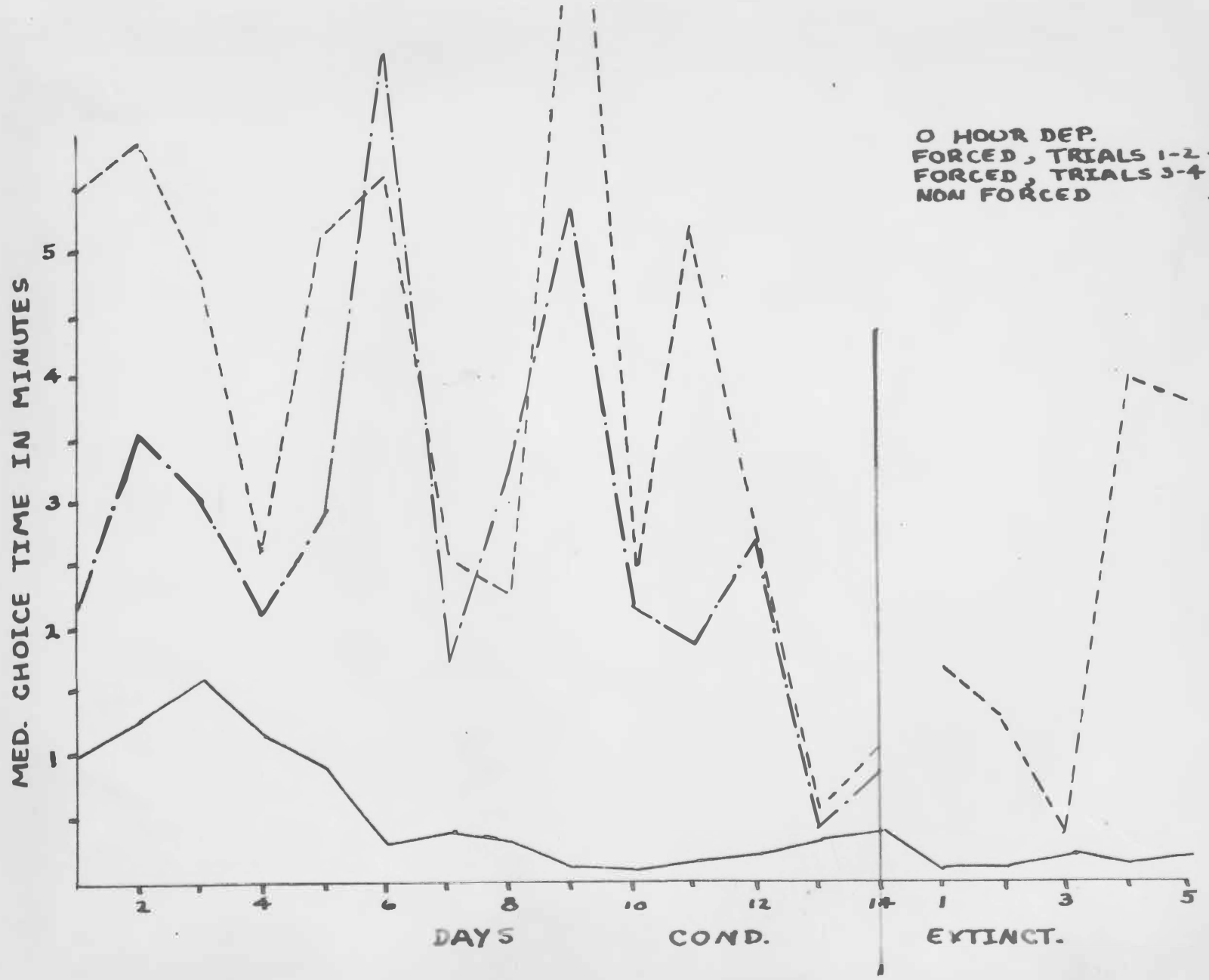

0 HOUR DEP.
FORCED, TRIALS 1-2
FORCED, TRIALS 3-4
NON FORCED
MED. CHOICE TIME IN MINUTES
1
2
3
4
5
2
4
6
8
10
12
14
1
3
5
DAYS
COND.
EXTINCT.

Fig. 7-a

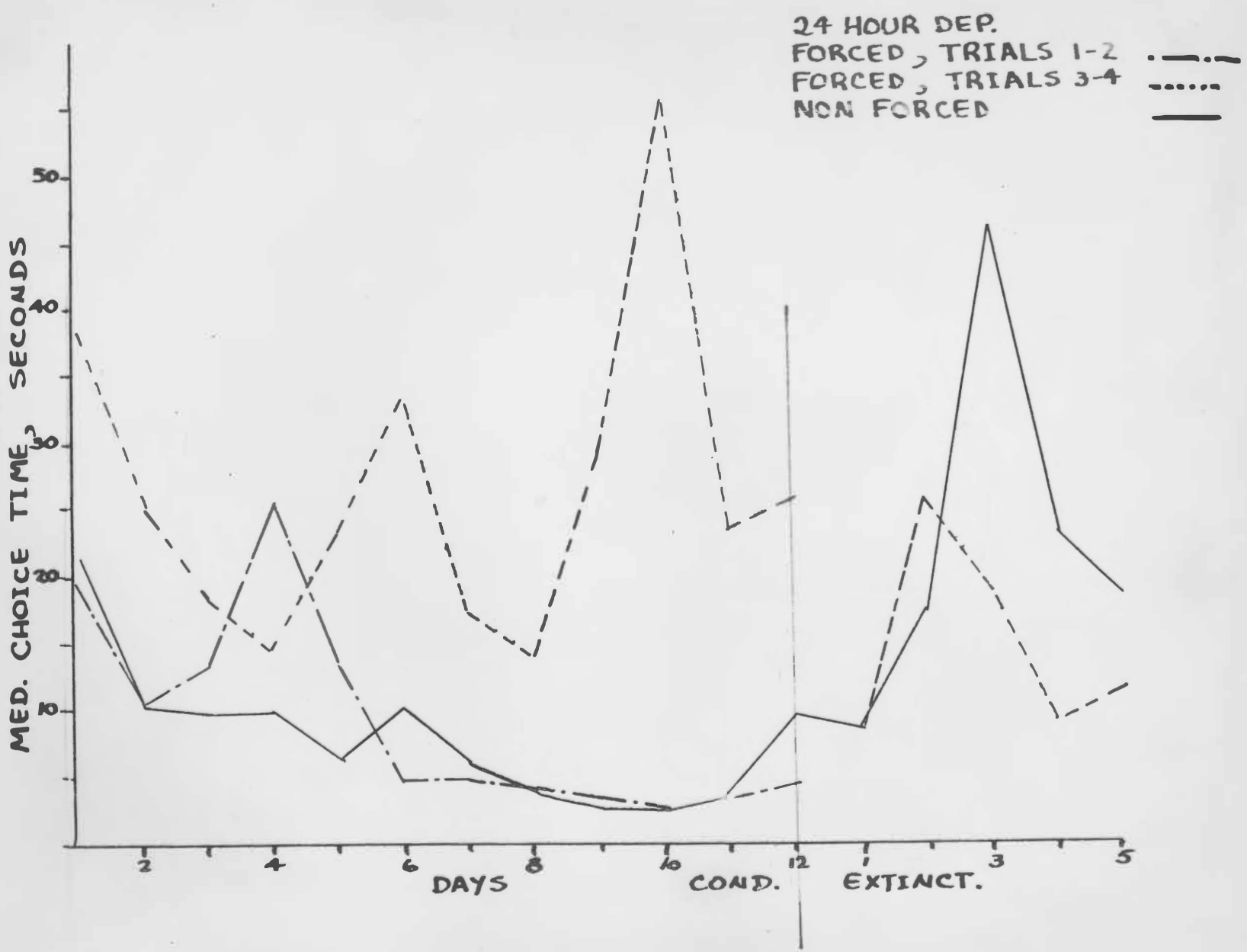

24 HOUR DEP.
FORCED, TRIALS 1-2
FORCED, TRIALS 3-4
NON FORCED
MED. CHOICE TIME, SECONDS
50
40
30
20
10
2
4
6
8
10
12
1
3
5
DAYS
COND.
EXTINCT.

Fig. 7-b

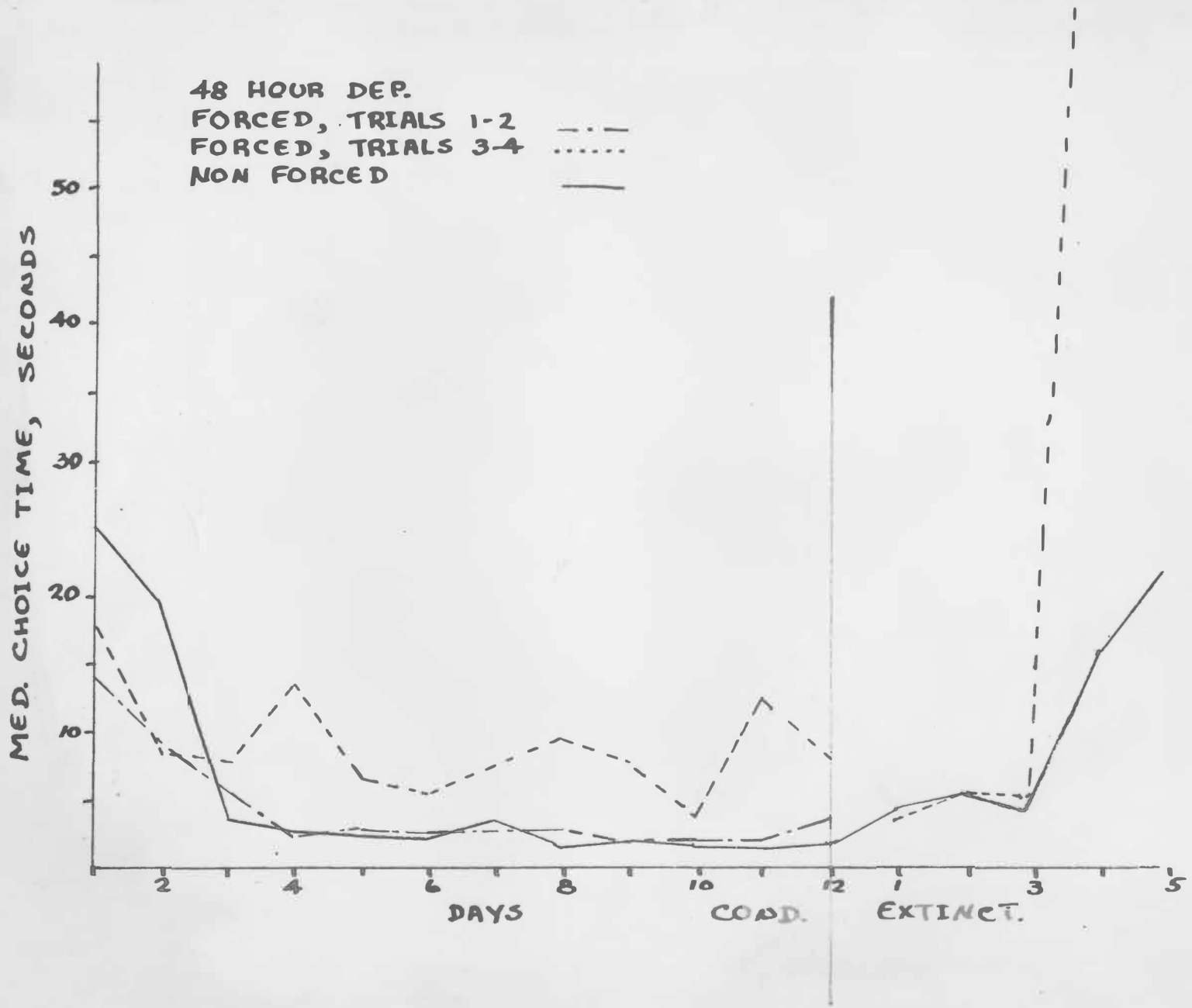

48 HOUR DEP.
FORCED, TRIALS 1-2
FORCED, TRIALS 3-4
NON FORCED
MED. CHOICE TIME, SECONDS
50
40
30
20
10
2
4
6
8
10
12
1
3
5
DAYS
COND.
EXTINCT.

Fig. 7-c

For the zero deprived rats the non-forced rats have much lower choice times than the forced rats, so much so that neither trials one and two nor trials three and four of the forced rats have lower choice times for any day of conditioning than the non-forced rats. Within the forced group trials one and two (the non-forced trials) have higher choice times than trials three and four (the forced trials), 11 out of 14 times. The non-forced group shows a smooth decline in choice time to an asymptote and then remains at or near the asymptote both during conditioning and extinction. The forced animals, both in conditioning and extinction, on the other hand, show great day to day variability and little evidence of reduction in choice time.

For the 24 and 48 hour groups, the trends are the same. There is no difference between the first two trials of the forced groups (the free choice trials) and the non-forced groups. After the first two or three days of conditioning, however, the third and fourth trials of the forced groups stop showing learning and rise somewhat, and are separated from trials one and two of the forced groups and from the non-forced group. For the remainder of conditioning the forced trials never fall to or below the level of the non-forced trials. The slowing of the

forced trials of the forced group as compared with the performance of the non-forced group is greatest for the zero deprivation animals and least for the 48 hour deprived animals, the 24 hour group falling between these two groups.

During extinction, although one rat of the 48 hour group died, leaving only three rats, it is of interest to note that two of these three refused to choose during the last day and one refused during the fourth day of extinction. None of the non-forced 48 hour deprivation group refused to make a choice during extinction. This is why the 48 hour deprived forced group shows such a tremendous rise in choice time during extinction.

At each deprivation level a grand median test was done between the non-forced group and the forced group, both for trials one and two and trials three and four. Table VII gives the P's obtained at each deprivation level between the non-forced group and trials three and four of the forced group, using Fisher's Exact test (15) and also a combined P of P's. This was done for both the first and second half of conditioning. There were no significant differences between the non-forced group and trials one and two of the forced group. It can be seen that the forced vs. the non-forced trials is significant at all levels of deprivation for the second

TABLE VII

NUMBER OF ANIMALS AT EACH DEPRIVATION LEVEL ABOVE AND BELOW THE MEDIAN CHOICE TIME OF THAT LEVEL

Group	First Half Cond. # Above Median	First Half Cond. # Below Median	P	Second Half Cond. # Above Median	Second Half Cond. # Below Median	P
0 Hr. Dep. Forced Group Forced Trials	4	1		4	1	
			.10			.10
0 Hr. Dep. Non-Forced Group	1	4		1	4	
24 Hr. Dep. Forced Group Forced Trials	4	1		5	0	
			.10			.004
24 Hr. Dep. Non-Forced Group	1	4		0	5	
48 Hr. Dep. Forced Group Forced Trials	2	2		4	0	
			.64			.01
48 Hr. Dep. Non-Forced Group	2	3		0	5	
P of p's χ^2	9.70			24.66		
P of p's	.20 P .10			.001		

half of conditioning and yield a P of P's that is highly significant. Note that during the second half of conditioning only one forced animal overlaps into the non-forced distribution.

c. Total-minus-choice time. This measure was employed to see how much of any obtained decrement in running time was due to the choice point conflict and how much was due to having to run away from a reinforcing goal. Figure 8--a, b, c, shows the total minus choice time at each deprivation level for the non-forced group, trials one and two of the forced group and trials three and four of the forced group. Table VIII shows the probability, using the grand median test of the non-forced groups and trials three and four of the forced group falling above and below the median.

It can be seen from Figure 8--a that for the zero deprived group there is some difference between the forced and non-forced groups but by the second half of conditioning this difference is small though significant (Table VIII). Unlike choice time, this measure shows a good drop over time and much less day to day variation. By the end of conditioning there is no significant difference between the forced and non-forced animals, regardless of which trials are compared. This

Figure 8--a, b, c

Median Total-Choice-Time per Trial During Conditioning and Extinction

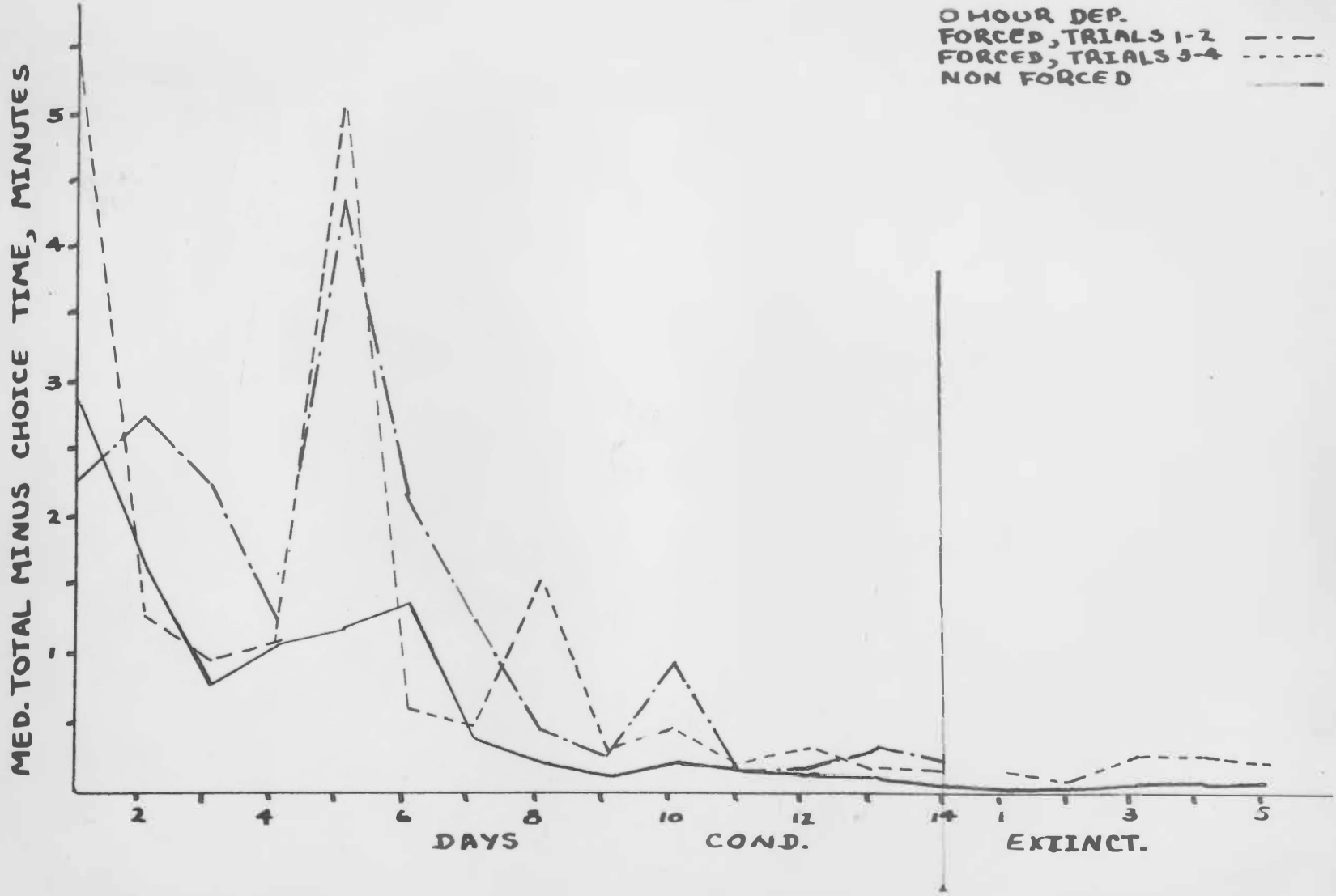

0 HOUR DEP.
FORCED, TRIALS 1-2
FORCED, TRIALS 3-4
NON FORCED
MED. TOTAL MINUS CHOICE TIME, MINUTES
1
2
3
4
5
2
4
6
8
10
12
14
1
3
5
DAYS
COND.
EXTINCT.

Fig. 8-a

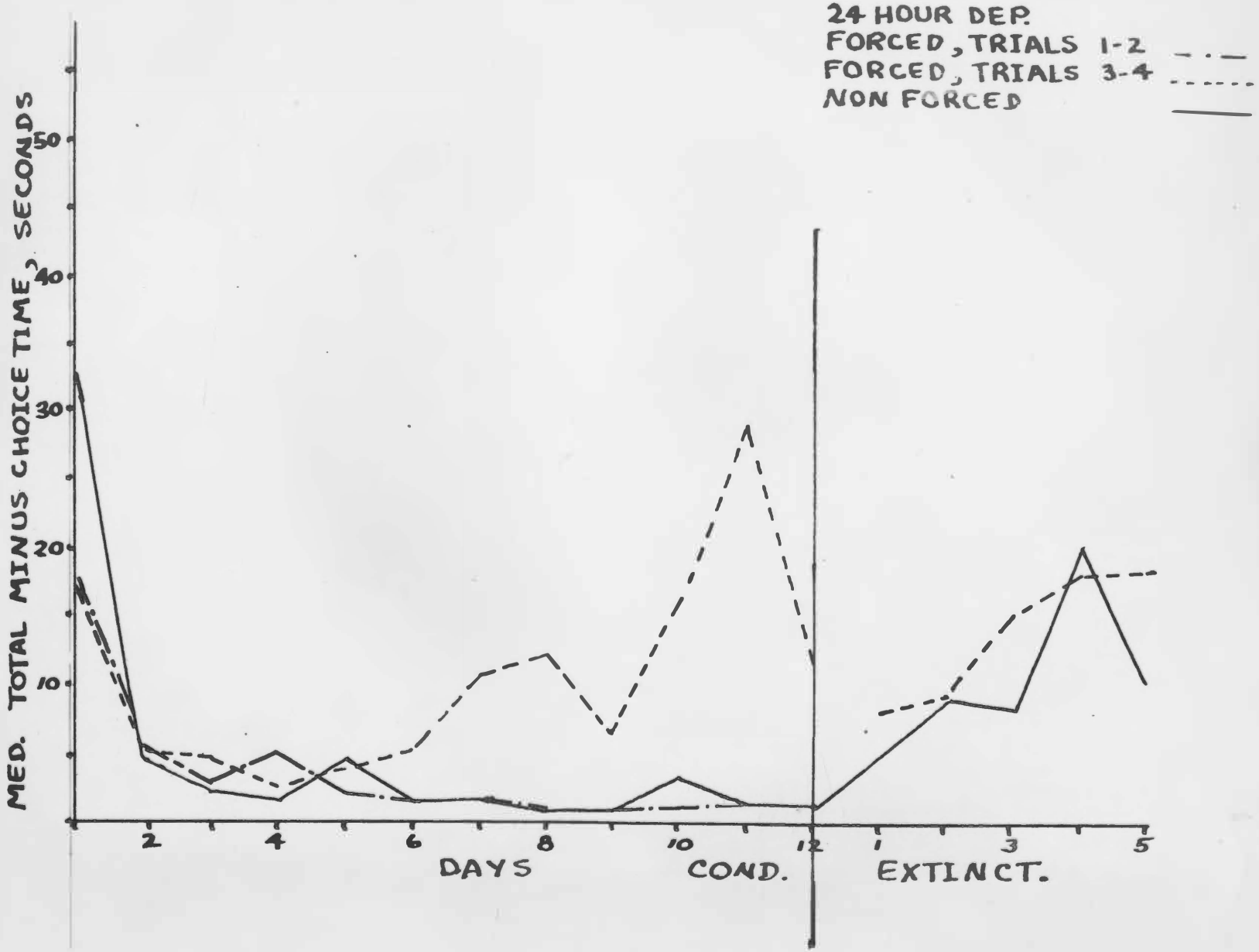

24 HOUR DEP.
FORCED, TRIALS 1-2
FORCED, TRIALS 3-4
NON FORCED
MED. TOTAL MINUS CHOICE TIME, SECONDS
50
40
30
20
10
2
4
6
8
10
12
1
3
5
DAYS
COND.
EXTINCT.

Fig. 8-b

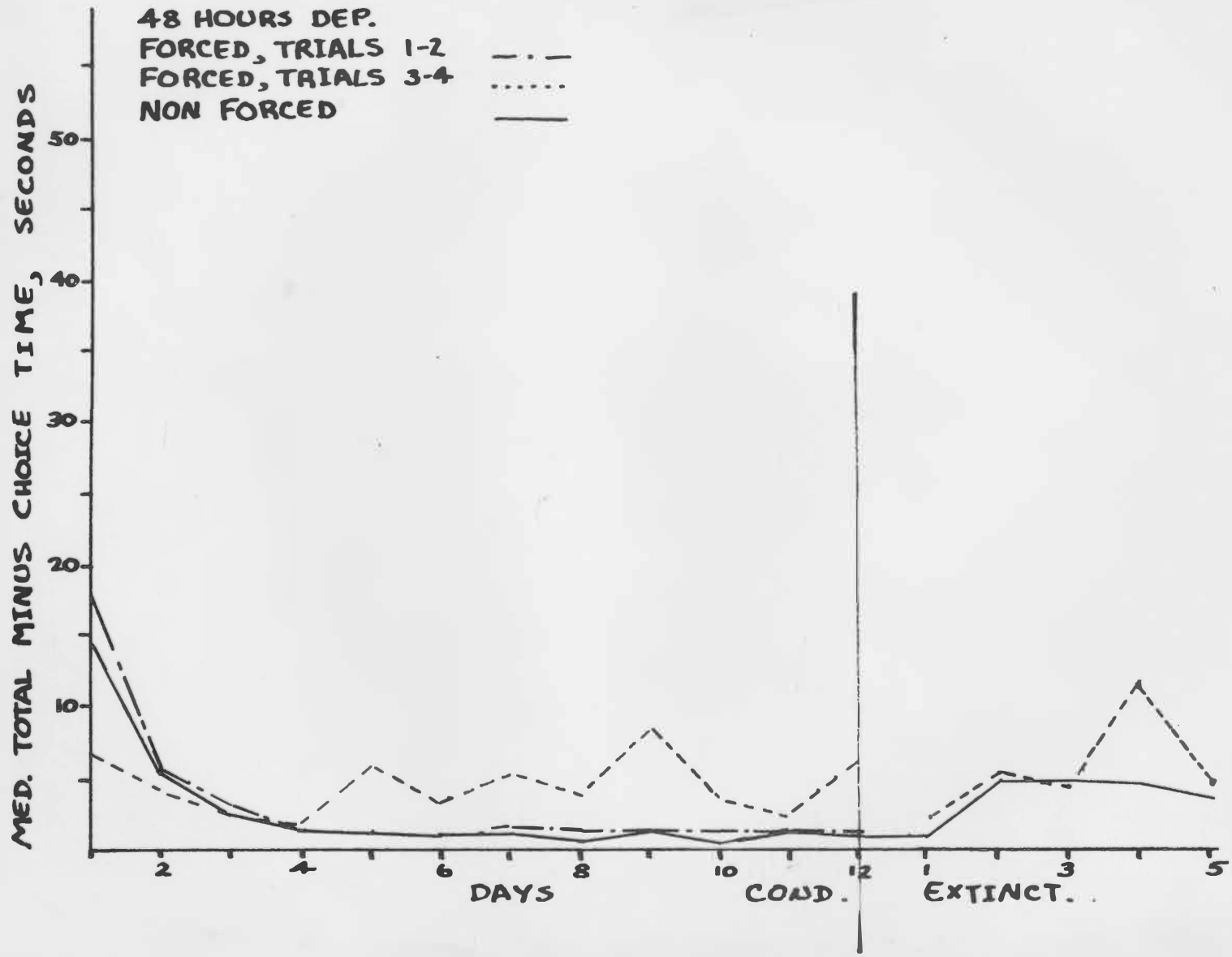

48 HOURS DEP.
FORCED, TRIALS 1-2
FORCED, TRIALS 3-4
NON FORCED
MED. TOTAL MINUS CHOICE TIME, SECONDS
50
40
30
20
10
2
4
6
8
10
12
1
3
5
DAYS
COND.
EXTINCT.

Fig. 8-c

TABLE VIII

NUMBER OF ANIMALS AT EACH DEPRIVATION LEVEL ABOVE AND BELOW THE MEDIAN TOTAL-MINUS-CHOICE TIME OF THAT LEVEL

Group	First Half Cond. # Above Median	First Half Cond. # Below Median	P	Second Half Cond. # Above Median	Second Half Cond. # Below Median	P
0 Hr. Dep. Forced Group Forced Trials	3	2		4	1	
			.50			.10
0 Hr. Dep. Non-Forced Group	2	3		1	4	
24 Hr. Dep. Forced Group Forced Trials	3	2		4	1	
			.50			.10
24 Hr. Dep. Non-Forced Group	2	3		1	4	
48 Hr. Dep. Forced Group Forced Trials	3	1		4	0	
			.24			.01
48 Hr. Dep. Non-Forced Group	1	3		0	5	
P of p's X^2	5.63			19.02		
P of p's	.20			.01		

is also true for extinction.

For the 24 and 48 hour groups, the trends are again the same and also similar to the choice time situation. There appears to be consistent and significant slowing down in the forced trials. As in choice time, the slowing is greater for the 24 hour group than for the 48 hour group.

There are no significant differences between the forced and non-forced groups in extinction for the 24 and 48 hour deprivation groups. For reasons mentioned above, the last two days of the 48 hour group must be considered cautiously.

d. Running time as a function of drive. A non-parametric analysis of variance was performed on the total-minus-choice times within the forced and non-forced groups to test the effect of drive. For the forced group the X^2_H during the first half of conditioning was 9.63 and for the second half of conditioning was 9.14. For the non-forced groups the X^2_H value for the first half of conditioning was 9.60 and for the second half of conditioning was 8.58. At two degrees of freedom these chi square values are significant at below the .02 level. Most of this difference, however, was due to the zero deprived groups and a Mann-Whitney test

for the differences between the 24 and 48 hour deprivation drive levels fail to yield any significant differences for either the forced or non-forced group regardless of which half of conditioning is tested.

e. Behavioral measures. Two behavioral measures were used: one was failure to make a choice in ten minutes, and the other was the number of stem traversals between B and C in the maze (see Figure 4). If the animal left the box and made a choice without retracing he was scored as having made one B-C traversal. If after getting to point C he came back to point B and then to C again, he has made two traversals, etc. Table IV gives the average number of B-C traversals for each animal and the number of DNC's (did not choose) for each animal.

Table IX shows that during conditioning only animals in the zero deprived group failed to make a choice within the ten minute time limit. Four-fifths of the forced animals failed, at some time, to make a choice. Only one-fifth of the non-forced animals ever failed to make a choice. This animal did not fail to make a choice during the last six days of conditioning or during extinction. Using the Wilcoxon non-parametric test for unpaired replicates, the difference is significant during conditioning at approximately the .03 point.

TABLE IX

NUMBER OF FAILURES TO MAKE A CHOICE AND AVERAGE NUMBER PER TRIAL OF B-C TRAVERSALS

Group	Rat#	Number Failures to Choose		Average B-C Traversals	
		Cond.	Extinc.	Cond.	Extinc.
0 hr. Dep. Forced	3	35	15	5.98	4.30
	4	13	5	4.32	1.65
	20	3	2	3.02	2.05
	26	21	0	1.77	1.65
	29	0	0	1.21	1.00
0 hr. Dep. Non-Forced	2	0	0	1.00	1.00
	9	0	0	1.11	1.00
	17	7	0	4.86	1.65
	27	0	0	1.61	1.10
	30	0	0	1.07	1.05
24 hr. Dep. Forced	6	0	0	1.38	1.10
	14	0	0	1.17	1.25
	19	0	0	1.38	1.05
	22	0	1	1.38	1.40
	28	0	0	1.15	1.25
24 hr. Dep. Non-Forced	10	0	0	1.00	1.00
	11	0	0	1.00	1.05
	12	0	0	1.00	1.10
	15	0	1	1.04	1.38
	23	0	died	1.00	died
48 hr. Dep. Forced	5	0	3	1.02	1.00
	7	0	7	1.13	1.05
	13	0	0	1.13	1.00
	24	0	0	1.27	1.05
48 hr. Dep. Non-Forced	1	0	0	1.04	1.04
	8	0	0	1.00	1.00
	16	0	0	1.00	1.00
	21	0	0	1.00	1.00
	25	0	0	1.00	1.00

During extinction none of the zero deprived non-forced animals failed to make a choice while three out of five of the zero deprived forced animals failed to do so, for some trials.

Considering all animals during extinction, six of the fourteen forced animals (see Table IX) failed to make a choice at least once, while only one out of fourteen animals of the non-forced animals failed to make a choice.

Comparisons of the forced and non-forced animals' number of B-C traversals in conditioning using Wilcoxen's non-parametric test for groups of unpaired replicates show that the forced animals traversed significantly more at well below the .01 point.

During extinction this difference tends to be maintained but just fails to reach the .05 point of significance.

Discussion

Running time. Although it was predicted that the results of forcing on time scores would be detrimental and would have different effects at different deprivation levels the direction of this effect was opposite that which was expected. It was felt that the emotional concomitants of forcing would be greatest for the 48 hour hungry rats when they were forced to run away from

food and consequently they were expected to show the greatest slowing during the forced trials. However, they showed the least and the non-deprived animals showed the greatest effects not only in time measures but in behavioral measures. The situation is evidently more complex than it appears to be at first glance. Looking at the error results of the non-deprived animals gives us a good lead for part of the explanation. We find that the non-forced non-deprived rats showed error scores significantly above a chance level of .50. This in itself is not surprising since each animal's "correct" side was defined as the side opposite its position preference. After the first two days, in which the animals probably were exploring the maze, the non-forced group went consistently to their preferred side more often than their non-preferred side. Forcing, on the other hand, seems to break up this habit and put the animals at a near chance level of responding as far as errors are concerned. This seems, judging by their reactions, to be behavioraly disturbing to the rat as indicated by his choice time. Since the total-minus-choice time shows a general trend very much like that of the non-forced rat we can assume that it is the choice point conflict and not the running away from the preferred side that is important in the non-deprived case. The

importance of the position preference in non-deprived rats was shown by a test which was run in order to determine if hunger itself breaks up a position habit. It was found that 18 out of 20 hungry rats alternated their first and second choice in the T-maze while only three out of ten satiated rats did. For the non-forced animals, the reinforcement from going to a position preference is greater than any reinforcement value the food may have even though the rats were often observed sniffing the food and occasionally eating.

In considering the results of the non-deprived animals, the extinction must be considered as an extension of the conditioning or learning since presence or absence of food appears to be unimportant in both. If the extinction phase is considered as conditioning, it will be seen that the choice time for the forced animal is still elevated while the total-minus-choice time is now at the level of the non-forced animals.

Latency. The results of the latency times for the non-deprived forced and non-forced group was unexpected. Latency is usually considered to be positively correlated with running time. Hall and Kobrick (20) reported a correlation of .45, yet here we have the group with the highest running time having the lowest

latency. Comparing the forced to the non-forced trials within the forced group indicated that forcing tended to make latencies higher but the forced latencies are still considerably lower than the non-forced groups' latencies. A possible explanation for this discrepancy lies in the differential between total number of trials for the forced and non-forced group, and the former having twice as many trials as the latter. Since during the last part of conditioning (the "extinction" period) this difference becomes smaller though still significant, this hypothesis is likely.

Since position preference is probably not important in the deprived animals one would still expect the 48 hour deprived animals to show greater effect from being forced away from food than the 24 hour group. One possible explanation of why this was not so is suggested from the activity study previously reported in this paper. It was then suggested that hunger may actually cause a decrease in non-locomotory behavior and an increase in locomotion. If this is so then we might expect the 48 hour hungry animals to run faster, even when going away from food, than the 24 hour hungry rats. Although one of the 48 hour rats died during extinction, there is strong evidence that during conditioning some sort of emotional

effect was being built up from being forced to run away from food since in the later stages of extinction two of these animals refused to make a choice and just sat at the choice point even though they were not being forced during extinction. This behavior was similar to that of the zero-deprived forced animals during conditioning.

Considering the effect on running time and the behavior of the non-deprived forced rats, it would appear that this forcing technique is a poor one to use with satiated or non-hungry rats.

Of the studies mentioned earlier using forcing, several used satiated or near satiated groups. Teel and Webb (66) ran rats hungry in a maze for four trials, then satiated them and gave them two more trials. Trials three and four were forced and the second satiated trial (trial six for the day) was also forced. They found that the animals did as well in choosing the correct side when satiated as they did when they were hungry. Since the data presented in the present study indicated that it is behavioraly disturbing for the animal to be forced, Teel's results could be explained by assuming that the animal on his first satiated trial is not responding to the correct side but avoiding a behaviorally disturbing stimulus. In other words, their results can

be explained on the basis of forcing.

In another experiment, Teel (65) ran rats at 1, 7, 15, and 22 hours food deprivation in a T-maze, using the above forcing technique. He found no differences in learning or extinction for any group using errors as a criterion. He reports no difficulty in having the one hour deprived rats run but reports no times or how often a rat was removed from the maze for failure to finish. Had he used non-forcing procedures, it is quite likely that the one hour group at least would have been poorer at learning even by his criterion than the other deprivation levels.

Looking at the latent learning or incidental learning experiments we find a very interesting thing. Latent learning experiments in which the animals are satiated for both food and water will show latent learning when later motivated for either food or water. Seward (47), Spence (60), and Kendler (27) have all gotten this result. Latent or incidental learning is also obtained when the animal is strongly motivated for both objects in the conditioning situation. Kendler (28) and Tolman (64) got latent learning when the motivation for the pertinent and non-pertinent reinforcement were equal. In all experiments in which drive for the pertinent

reward is strong and reward is given and the drive for the incidental reward is weak no significant evidence of latent learning is obtained. Since the present study indicates that satiated animals may have difficulty from the forcing procedure, it would appear that forcing should be used, if at all, with moderately motivated animals.

In such a situation only errors or free choice time should be measured. If the motivation is great, the present study suggests that there will result some sort of behavioral disturbance during extinction.

In straight learning experiments forcing seems to be a doubtful tool. If we are trying to compare animal learning to human learning we should not use a technique which forces the organism to do the wrong thing since this is seldom if ever done in human learning. From a standpoint of experimental economy the technique is also poor in that it in no way improves the learning and takes more than twice as long as non-forcing procedures to run each rat.

In examining Denny's studies on the role of "secondary reinforcement" when the animal goes to the wrong side, there appears to be nothing in this present study to suggest that his use of forcing is invalid or may cause difficulties. However he does not report his

extinction data. Siegel's use of forcing to equate initial response strength also appears valid.

Two factors still need investigation in this area. The first is the effect of forcing over very long periods of conditioning at widely different drive levels and the shape of the extinction curve if carried out over a greater number of days than was done in this study. There is evidence to suggest that this may yield a curve, especially at high hunger levels, which shows great decrement and then falls back to a point indicating normal extinction.

Summary

Two groups of rats, matched for age, sex, and activity, were used. One group was run four times a day and was forced on the last two trials to go in the direction opposite that taken on the first two trials. The other group had two free choice trials a day.

Each group was divided into three sub groups of zero, 24, and 48 hours food deprivation. The zero group was run for 14 days, the 24 and 48 hour groups were run for twelve days. The correct side of the T-maze for each rat was opposite its position preference. After conditioning, the rats were given four extinction trials a day for five days.

These were all free choice for all groups. Measures used were errors, latency, time to make a choice and total running time minus choice time, stem traversals, and failure to choose.

It was found that the forced group had lower latencies than the non-forced group for the zero deprived rats. The 24 and 48 hour hungry animals, forced and non-forced groups were not significantly different as far as errors are concerned. The non-hungry non-forced group had consistently above chance errors and the forced non-hungry animals fluctuated at chance.

In choice time and total time minus choice time, the forced trials of the forced animals at all deprivation levels were slower than the non-forced animal. This effect for choice time was greatest for the zero deprived forced group and least for the 48 hour deprived forced group as compared with the non-forced control groups. In total-minus-choice time, the zero hungry rats showed little effect of forcing but the 24 and 48 hour forced group showed a significant and consistent effect for their forced trials with the 24 hour group showing the greatest slowing.

In two behavioral measures, failure to make a choice and number of traversals between the start box

and choice point, the forced non-hungry animals were significantly higher than the non-forced zero deprived animals. Forced animals at all levels of deprivation showed significantly more traversals on all trials between the start box and choice point than non-forced animals.

It was suggested that a forcing technique should only be used when the animals are not satiated and never used in a straight T-maze learning situation since it is time consuming, gives no advantage in speed of learning, and significantly increases running time. For certain latent learning situations, it appears to be a valid technique at moderate motivational levels.

CHAPTER IV

THE RELATIONSHIP BETWEEN ACTIVITY AND MAZE PERFORMANCE

It has been previously pointed out in this paper that one should try to specify what type of activity is being measured before much sense can be made of the effect of the independent variables used. If we were interested in the relationship between activity and some other response of the rat, such as maze performance, we would want to determine on an a priori basis what element the two situations have in common. Maze learning involves two easily discernible responses in the white rat: running and, at one or more points, choice of direction. Considering the first response, running, and its relationship to activity, one would naturally wish to determine what activity one is dealing with. If the activity is measured on an activity wheel, we can be fairly sure that we are dealing with activity of a locomotory nature. If, on the other hand, the activity was measured on the types of stabilimeters used in the second chapter of this paper, we have some evidence to believe that we are dealing with a mixture of locomotory and non-locomotory activity with more emphasis on locomotory activity

with the microswitch apparatus and more emphasis on the non-locomotory using the contact apparatus.

If these assumptions hold, then it should be possible to make some guesses as to the relationship between these various kinds of activity and maze performance. They are as follow:

1. The higher the activity on an activity wheel, the faster the running in a maze.

2. The higher the activity in the sensitive stabilimeter of the contact type used in this paper, the slower the running time.

3. The relationship between the activity measured on the microswitch apparatus and running time should fall somewhere between 1 and 2.

4. If we assume fast running times go with rapid learning in terms of error (1) scores then we should expect the same relationships to hold as far as errors are concerned.

These relationships will be considered as the hypotheses for this chapter.

Shirley (49) has anchored the values for us in regard to activity wheels and running times in a maze. The maze that she used is somewhat more complex than the

T-maze used in this paper but she reports satisfactory odd-even reliability with it. If we consider that high activity going with low running times is a positive correlation, she found, in two separate studies, correlations of +.40 and +.46 respectively between activity and running time. Ligon (36) also found a correlation between running time and activity of +.46. He does not report on correlations between activity and errors, but Anderson (1) got a correlation of +.357.

Using Anderson's and Shirley's values as a base from which to estimate the area of correlations between the two types of apparatuses used in this paper, we can guess that the correlations between the microswitch apparatus and running time will be near zero but possibly low positive. The correlation between the contact apparatus and running time will also be low but in a negative direction. The same general estimates are made in regard to errors.

Method

The rats used in this study are the same ones used in the second and third part of the activity study reported in this paper. These were also the same rats

used in the T-maze forcing experiment. This chapter merely attempts to correlate the findings of chapter two and three. The rats measured for activity on the micro-switch machines comprised the non-forced group and the rats measured on the contact machines comprised the forced group. Since forcing itself had a great effect on certain measures of running time in the maze only total minus choice time is used for the forced rats as a measure of running in the maze and only the first two trials of each day are used. The other measure of running in the maze is latency. Errors are the third maze measure to be correlated with activity. All correlations are done with the rank order method since the number of animals is small. Since it may well be that activity is more related to running time early in maze learning, the measures used for running time are considered for the first and second half of conditioning. It is regrettable that the number of animals is so small for correlational analysis and the results must be interpreted with caution and are of an exploratory nature only.

Results

Table X gives the rank order correlations between activity and the various measures used in the maze study.

TABLE X

RANK ORDER CORRELATIONS BETWEEN ACTIVITY AND THREE MEASURES OF MAZE PERFORMANCE

	Activity Apparatus		
Maze Measure	Activity Wheel (Shirley's and Anderson's results)	Microswitch Stabilimeter	Contact Stabilimeter
Errors	+.357	-.05	-.44
Running Time	+.40, +.46		
First Half Cond.		-.10	-.50
Second Half Cond.		-.22	-.28
Latency			
First Half Cond.		+.26	+.05
Second Half Cond.		+.00	-.24

All rankings in the maze studies were done so that the lower the time or the lower the average error, the lower the rank. For activity, the higher the activity, the lower the rank so that a rank of one in any maze measure indicates fastest learning, and a rank of one in activity indicates that this animal was the most active. It can be seen that the three groups (including Shirley's and Anderson's study) fell in the order predicted for running time and errors, and that the two groups considered in this paper fell in their predicted position on the other measures.

Discussion

Omwake (41) and Liddell (35) have also done experiments in the area of relating activity to maze performance. Their results, however, are of little use because of the method in which the data was treated because of certain methodological considerations. Omwake, for instance, used a very complex maze in which animals were given only two trials, the second trial being the trial correlated to activity. Learning is defined by the amount of time needed to find the reward and activity is defined by number of errors per minute. She reports

a correlation of .71 between activity and learning but since the activity measure is defined in terms of maze performances, this relationship is not surprising, incapable of being interpreted, and is of little use. To further contaminate the results, rats who did not finish within a certain time were not counted.

Liddell (35) used pedometers to measure the activity of sheep and correlated this with running time in a moderately complex maze. Although he gives no correlation coefficients and reports that he observed little relationship between maze learning and activity, he did find, in twin sheep, 60-70% of the more active twins were faster in the maze.

Geier and Tolman (17) did an interesting study trying to determine the relationship, in a straight runway maze, between activity and distance from the goal. They used a straight runway maze, 24 feet in length with five activity wheels spaced equally and transecting the runway at right angles. As the rat proceeded down the runway he would enter the wheel and remain in it for one minute. The wheel then stopped and the rat proceeded down the runway until he came to the next wheel. The rats were at an "average hunger." The general shape of the function of activity and

distance to the goal was bowed; at the beginning of learning, the greatest activity was at the fourth wheel (the one second from the goal) and as learning progressed, the third and then the second wheel showed the most activity. Geier and Tolman call this restless activity ignoring its locomotory nature and also the fact during this experiment which lasted for 45 days, the rats' total activity increased, showing a negatively accelerated learning curve. Activity went from 400 revolutions a day at the beginning of the experiment to 1300 revolutions a day at the end. Their results would indicate that rats learn to be active at about the same rate that they learn to run the maze, that is, as running times decrease, activity increases. This would suggest that correlations between activity wheel measures and running speed in a maze may not be only due to the common element of running, but also, if activity on an activity wheel is learned to some extent, it can serve as an indication of ability to learn in other situations.

Summary

This chapter has been a correlational analysis of the behavior of the second group of rats used in the activity and T-maze study. Correlations were done between three measures of maze performance (running time, latency, and errors) and activity. It was predicted that the more a given apparatus measured locomotion, the higher the correlations would be between activity and maze learning. Using a study of Shirley's and Anderson's as part of the estimate, and the two apparatuses reported in this paper, the predicted trends were obtained. Because of the small number of animals used in this paper, however, caution is advised in interpreting the obtained correlational coefficients.

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APPENDICES

APPENDIX A

INDIVIDUAL RAT ACTIVITY DATA EXPRESSED IN STANDARD DEVIATION UNITS

CONTACT APPARATUS, PARTS ONE AND TWO OF EXPERIMENT I

Rat Number*	Pre-Deprivation Activity in S.D. Units, Three Day Average						Post-Deprivation Activity in S.D. Units, Three Day Average				
	Zero Deprivation Group, Part One										
	Days						Days				
	1-3	4-6	7-9	10-12	13-15	$\bar{X}$	1-3	4-6	7-9	10-12	$\bar{X}$
4 F	1.21	.60	1.31	.73	1.47	1.06	1.03	1.01	1.51	1.19	1.19
9 F	2.21	2.06	2.10	1.17	1.86	1.88	1.83	1.52	1.81	1.53	1.67
15 F	1.53	2.78	2.13	1.40	1.41	1.85	.83	1.16	1.98	1.38	1.34
17 M	1.59	1.60	1.15	1.38	1.63	1.47	.94	1.61	1.58	1.21	1.34
22 F	1.91	1.64	1.22	1.38	1.84	1.60	1.23	1.46	1.58	1.22	1.37
25 F	.97	1.77	1.74	1.78	2.33	1.72	1.33	1.61	1.87	1.65	1.62
56 M	.71	1.01	.34	.91	.97	.79	1.04	1.33	1.68	.95	1.25
28 F	1.83	.90	1.34	1.81	1.55	1.49	1.35	1.56	1.61	1.05	1.39
30 F	1.61	1.32	1.83	.99	1.55	1.46	1.48	1.63	1.94	2.38	1.86
10H M	1.44	1.51	2.17	3.48	2.59	2.24	1.80	1.46	2.48	2.36	2.02
	Zero Deprivation Group, Part Two										
3 M	1.23	.92	.77	.91	.76	.92	.70	1.12	2.13	1.18	1.28
4 F	1.06	.91	.53	.37	.73	.72	.27	.88	1.50	.51	.79
20 M	2.22	1.63	2.29	1.70	1.84	1.94	.97	1.85	1.18	1.19	1.30
26 M	.72	1.20	.61	.94	.87	.87	.63	1.33	1.67	1.84	1.37
29 F	.56	1.45	1.64	1.69	1.02	1.27	1.57	1.43	1.03	2.01	1.51

*F--Female; M--Male.

CONTACT APPARATUS, PARTS ONE AND TWO OF EXPERIMENT I

Rat Number*	Pre-Deprivation Activity in S.D. Units, Three Day Average						Post Deprivation Activity in S.D. Units, Three Day Average				
	24 Hour Deprivation Group, Part One										
	Days						Days				
	1-3	4-6	7-9	10-12	13-15	$\bar{X}$	1-3	4-6	7-9	10-12	$\bar{X}$
2 F	.76	.86	1.01	.65	1.08	.87	.76	.73	1.18	1.09	.94
3X F	1.72	1.33	1.25	2.16	1.10	1.51	.43	.62	1.69	1.09	.96
3 M	1.06	1.33	1.12	1.72	1.56	1.36	1.33	1.21	1.26	1.61	1.35
8 F	.51	2.06	.54	1.67	2.66	1.49	1.10	.64	1.08	2.12	1.24
16 F	1.73	1.59	1.70	1.65	1.84	1.70	1.57	1.66	2.10	1.45	1.70
18 M	1.66	2.36	2.31	1.38	1.66	1.87	.83	1.48	1.80	2.18	1.57
19 F	1.41	1.78	1.55	1.25	2.80	1.76	1.06	1.78	1.83	1.22	1.47
23 F	1.33	1.40	2.07	1.33	1.52	1.53	1.09	1.47	1.65	1.36	1.39
29 M	1.21	.85	1.00	.85	1.00	.98	.85	.50	1.14	1.12	.90
34 F	1.77	2.49	1.55	1.37	1.18	1.67	1.36	1.86	1.67	2.05	1.73
	24 Hour Deprivation Group, Part Two										
6 F	1.39	.96	1.85	1.20	.58	1.20	.81	1.26	.95		1.01
14 F	1.50	2.01	1.33	1.56	1.55	1.59	.57	1.14	.81		.84
19 M	1.03	.99	.87	1.00	.81	.94	.41	1.82	.67		.96
22 M	.95	.95	.83	.64	.86	.85	.56	1.17	.54		.76
28 F	.63	.92	.61	.60	.98	.75	.42	.78	.55		.58

*F--Female; M--Male.

CONTACT APPARATUS, PARTS ONE AND TWO, EXPERIMENT I

Rat Number*	Pre-Deprivation Activity in S.D. Units, Three Day Average						Post-Deprivation Activity in S.D. Units, Three Day Average				
	48 Hour Deprivation Group, Part One										
	Days						Days				
	1-3	4-6	7-9	10-12	13-15	$\bar{X}$	1-3	4-6	7-9	10-12	$\bar{X}$
5 M	1.02	1.98	1.39	1.80	1.76	1.59	.79	.59	.85	.78	.75
7 F		1.75	2.51	2.24	1.37	1.97	1.19	1.14	1.76	1.91	1.50
12 M		.99	1.62	1.59	1.59	1.45	1.00	.86	1.47	.87	1.05
13 F	1.69	2.78	1.95	2.68	2.33	2.29	.89	.66	1.04	.62	.80
14 M		.63	.86	.87	1.28	.91	1.86	1.58	1.30	.95	1.42
20 F		1.42	2.41	2.22	2.20	2.06	2.16	1.66	1.92	1.76	1.88
21 F	.93	.64	1.15	1.17	1.49	1.08	1.62	1.07	1.60	.97	1.32
4H M			1.58	.91	1.98	1.49	1.36	1.27	1.54	.49	1.17
9H F			1.19	1.07	1.48	1.25	1.07	.89	1.40	.59	.99
34H F			1.84	1.00	2.45	1.76	1.92	1.84	1.32	1.11	1.55
	48 Hour Deprivation Group, Part Two										
							1-3	4-6	7		$\bar{X}$
5 M	.97	.98	.74	.60	.99	.86	.86	.75	.28		.55
7 F	1.71	1.26	1.18	1.25	2.25	1.53	.83	.49	1.28		.87
13 M	1.10	.91	.79	.54	.76	.82	.87	.68	.89		.81
18 F	.97	1.24	.65	.54	.87	.85	.38	.45	.95		.66
24 M	1.00	1.01	.54	1.37	1.05	.99	1.12	.92	.95		1.00

*F--Female; M--Male.

CONTACT APPARATUS, PART ONE, EXPERIMENT I

Rat Number*	Pre-Deprivation Activity in S.D. Units, Three Day Average						Post-Deprivation Activity in S.D. Units, Two Day Average		
72 Hour Deprivation Group, Part One									
	Days						Days		
	1-3	4-6	7-9	10-12	13-15	$\bar{X}$	1-2	3-4	$\bar{X}$
1 F	.60	.71	1.59	1.21	.71	.96	.45	1.15	.80
5 M	1.02	1.98	1.39	1.80	1.76	1.59	.69	.96	.83
6 F	1.21	1.85	2.25	1.11	3.08	1.90	1.85	1.11	1.48
11 F	1.32	1.53	1.69	1.13	1.92	1.52	1.60	2.59	2.09
13 F	1.69	2.78	1.96	2.51	2.33	2.25	1.22	1.92	1.57
27 F	1.08	1.31	1.11	1.11	1.74	1.27	.66	1.62	1.14
31 M	1.14	1.04	.44	.78	1.16	.91	1.02	.78	.90
32 F	1.77	1.83	1.39	1.65	1.47	1.62	1.70	1.90	1.80
33 F	2.09	1.82	1.23	1.28	.73	1.43	.63	2.01	1.32
27H M	.98	.58	.67	1.68	.61	.90	.74	1.01	.88

*F--Female; M--Male.

MICROSWITCH APPARATUS, PART TWO, EXPERIMENT I

Rat Number*	Pre-Deprivation Activity in S.D. Units, Three Day Average						Post-Deprivation Activity in S.D. Units, Three Day Average				
Zero Deprivation Group											
	Days						Days				
	1-3	4-6	7-9	10-12	13-15	$\bar{X}$	1-3	4-6	7-9	10-12	$\bar{X}$
2 F	1.52	1.12	1.71	1.43	1.45	1.45	1.18	1.17	1.39	1.11	1.21
9 M	.77	.82	.65	1.04	.89	.83	.91	.73	.63	.28	.64
17 F	1.15	.95	1.32	.56	.63	.92	1.08	1.18	1.15	.84	1.06
27 M	1.26	1.41	.74	.87	.99	1.05	.53	.80	1.01	.88	.81
30 F	.41	1.44	1.78	1.63	2.24	1.50	1.33	1.44	.87	1.41	1.26
24 Hour Deprivation Group											
10 M	1.08	.90	.71	1.04	.88	.92	.54	.80	.72		.69
11 M	.60	.73	.57	.55	1.04	.70	.82	.96	.72		.83
12 F	1.06	.88	1.14	.50	1.49	1.01	1.08	.84	.94		.95
15 F	1.37	2.09	1.08	1.21	1.69	1.49	.88	1.20	1.29		1.12
23 F	.83	.42	.52	.64	.87	.66	.69	.81	.85		.78
48 Hour Deprivation Group											
							1-3	4-6	7		$\bar{X}$
1 M	.92	1.15	.81	.48	.91	.85	.49	.69	.60		.59
8 F	1.32	1.37	1.01	.83	1.47	1.20	.75	.99	1.22		.99
16 F	1.52	1.23	.97	1.18	1.30	1.24	1.31	1.21	1.85		1.46
21 M	.64	1.30	1.16	1.03	.93	1.01	.76	1.39	.96		1.04
25 M	.66	.80	.67	1.06	.64	.77	1.06	.60	.30		.65

*F--Female; M--Male.

APPENDIX B

INDIVIDUAL RAT CONDITIONING AND EXTINCTION TIME MEASURES

ZERO DEPRIVATION GROUP, NON-FORCED

Rat No.	Days 1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Average Total-Minus-Choice Running Time in Seconds, Conditioning													
2	14.5	20.0	42.0	7.5	145.0	158.5	47.0	32.5	8.5	13.5	3.5	5.0	6.0	4.5
9	34.5	103.0	2.0	DNS*	22.0	6.5	2.5	2.0	1.5	1.0	2.0	1.0	2.5	3.5
17	176.0	312.5	287.5	199.0	74.0	DNC	DNC	15.0	47.0	82.0	55.5	9.0	8.0	5.0
27	189.0	85.0	47.5	17.0	1.5	2.0	0.5	1.0	1.5	1.5	8.0	57.0	78.5	3.0
30	361.5	308.0	75.5	11.5	316.5	178.5	172.5	90.5	46.5	51.0	33.0	13.5	78.5	60.0
	Average Choice Running Time in Seconds, Conditioning													
2	12.0	8.0	13.5	7.5	12.5	9.0	10.0	10.5	8.0	7.0	6.0	15.5	8.0	9.0
9	29.5	139.0	151.0	DNS	136.0	37.5	13.0	4.0	4.0	5.5	11.0	5.5	15.5	8.5
17	406.0	266.0	204.0	401.0	205.0	600.0	600.0	590.0	333.5	80.5	29.5	50.5	64.0	70.0
27	104.0	75.5	83.0	157.5	55.5	20.0	28.0	37.0	13.0	6.0	7.5	8.5	20.0	21.5
30	62.0	25.5	15.0	15.5	12.0	15.0	23.0	21.5	9.5	8.5	9.5	13.5	17.0	53.0
	Average Latency in Seconds, Conditioning													
2	4.9	5.3	7.4	5.7	5.0	5.6	7.4	7.6	2.4	2.8	2.9	2.1	3.7	6.8
9	16.4	30.8	180.0	180.0	178.4	100.0	111.6	180.0	77.9	13.98	29.6	9.72	4.4	13.3
17	15.8	21.6	59.3	23.0	48.6	47.1	45.7	29.9	11.8	40.0	4.5	18.6	15.3	9.2
27	17.4	11.7	53.0	21.3	53.8	86.6	39.1	139.6	38.08	2.6	36.0	4.7	55.4	67.4
30	28.6	11.5	6.6	6.6	4.2	4.0	5.0	2.5	4.5	3.1	2.8	2.6	10.2	14.5

*Did not start.

ZERO DEPRIVATION GROUP, NON-FORCED

Rat No.	Days				
	1	2	3	4	5
	Average Total-Minus-Choice Running Time in Seconds, Extinction				
2	2.2	2.8	4.8	5.5	5.8
9	3.0	1.5	2.0	5.5	5.2
17	8.5	5.8	3.8	6.2	4.8
27	4.0	4.2	3.8	7.0	4.5
30	41.8	14.5	31.0	15.2	19.2
	Average Choice-Minus-Latency Running Time in Seconds, Extinction				
2	6.5	5.8	12.5	4.2	5.0
9	13.8	16.0	11.2	12.5	12.0
17	59.8	36.0	13.0	62.0	66.0
27	6.5	4.5	13.5	8.0	15.8
30	8.5	5.2	8.2	9.5	8.5
	Average Latency in Seconds, Extinction				
2	1.0	0.7	4.6	1.9	0.8
9	4.7	4.8	5.8	2.9	8.7
17	20.7	15.1	3.5	3.9	19.0
27	6.1	1.8	6.9	6.2	28.3
30	2.1	3.6	12.8	6.0	6.2

24 HOUR DEPRIVATION GROUP, NON-FORCED

Rat No.	Days											
	1	2	3	4	5	6	7	8	9	10	11	12
	Average Total-Minus-Choice Running Time in Seconds, Conditioning											
10	36.6	4.1	1.6	1.2	5.6	0.8	1.4	1.1	0.7	7.9	1.6	1.5
11	13.4	4.9	2.1	0.8	0.8	1.8	1.0	1.0	1.0	0.6	0.6	1.4
12	30.1	3.9	2.0	1.6	2.8	0.8	1.9	1.2	1.1	0.8	0.8	1.5
15	108.7	34.9	16.6	3.6	4.6	7.4	3.6	4.9	6.0	20.9	11.8	4.6
23	19.9	8.5	3.6	3.6	5.1	2.2	9.6	3.2	1.3	3.2	2.8	10.4
	Average Choice-Minus-Latency Running Time in Seconds, Conditioning											
10	32.5	197.4	9.8	10.0	14.6	11.9	7.6	4.0	2.8	2.7	3.8	12.3
11	14.7	5.0	5.6	2.8	1.7	1.7	1.8	1.5	1.6	1.4	1.4	4.6
12	10.9	9.6	4.4	22.6	6.4	2.7	1.8	3.8	2.8	2.3	1.4	5.4
15	21.8	34.2	13.6	11.8	9.8	26.7	9.4	8.6	6.2	11.5	10.2	9.1
23	32.9	10.6	14.0	7.0	3.6	10.1	6.0	4.9	2.6	3.7	12.8	32.8
	Average Latency in Seconds											
10	28.4	146.7	27.6	74.0	35.8	8.9	5.2	2.2	2.2	4.6	5.9	2.4
11	8.2	4.5	5.2	0.7	1.4	1.1	0.6	0.6	0.9	0.6	0.5	0.6
12	4.0	5.3	8.0	5.8	1.8	1.6	1.6	0.8	1.3	0.9	1.1	0.8
15	8.0	4.8	33.4	12.4	5.6	49.5	2.6	1.6	2.9	9.1	4.0	0.8
23	5.6	5.2	3.3	4.2	5.3	5.5	1.9	1.3	0.6	1.7	0.8	5.3

24 HOUR DEPRIVATION GROUP NON-FORCED

Rat No.	Days				
	1	2	3	4	5
	Average Total-Minus-Choice Running Time, Extinction				
10	35.3	8.7	9.6	8.7	4.0
11	3.5	6.4	6.1	25.3	10.7
12	2.6	9.4	7.6	15.2	10.3
15	10.1	37.1	223.2	60.2	318.7
23	5.0	Died	---	---	---
	Average Choice-Minus-Latency Running Time, in Seconds, Extinction				
10	10.2	13.9	43.4	24.1	17.7
11	2.3	6.9	73.4	13.2	17.3
12	6.5	20.0	17.6	22.2	19.0
15	26.6	41.7	49.4	224.4	440.3
23	8.5	Died	---	---	---
	Average Latency in Seconds, Extinction				
10	2.6	15.1	58.2	6.2	41.4
11	0.8	0.6	1.18	0.6	5.8
12	0.8	9.5	1.8	1.4	9.2
15	0.7	2.0	2.7	8.8	5.9
23	0.5	Died	---	---	---

48 HOUR DEPRIVATION GROUP, NON-FORCED

Rat No.	Days											
	1	2	3	4	5	6	7	8	9	10	11	12
	Average Total-Minus-Choice Time in Seconds, Conditioning											
1	18.4	21.9	1.2	0.9	0.8	0.6	1.3	0.8	1.6	0.7	1.3	1.2
8	14.2	6.2	3.2	1.2	1.2	1.0	1.1	0.7	1.0	0.6	0.8	1.0
16	14.9	5.8	2.0	3.8	1.2	1.6	1.4	1.0	1.3	1.2	0.9	1.0
21	6.8	6.3	2.6	1.6	1.0	1.0	1.3	0.8	1.2	0.8	1.2	0.8
25	9.8	7.6	4.6	4.8	1.5	1.8	1.5	1.1	1.8	1.2	1.2	1.6
	Average Choice-Minus-Latency Running Time in Seconds, Conditioning											
1	213.3	365.1	3.4	2.2	1.6	2.4	7.0	2.0	4.4	2.0	2.8	3.7
8	9.6	10.8	2.9	1.8	1.7	1.5	3.4	1.6	1.4	1.2	1.4	1.2
16	39.8	43.1	12.8	4.2	2.4	4.8	3.0	2.0	1.8	1.5	1.4	1.6
21	11.2	3.5	2.8	2.6	2.4	2.4	3.4	1.8	2.0	1.9	1.6	1.9
25	25.0	19.0	4.6	4.4	2.5	4.0	2.7	1.8	2.6	1.8	1.7	1.9
	Average Latency in Seconds, Conditioning											
1	118.4	56.4	38.9	7.3	10.0	14.72	3.78	2.3	5.2	1.1	1.0	0.7
8	5.7	9.5	11.3	0.8	0.6	2.1	0.6	0.6	0.4	0.4	0.6	0.5
16	25.9	4.3	11.2	4.5	1.2	2.3	5.8	1.0	1.9	0.9	0.5	0.7
21	14.5	1.3	1.0	0.8	0.8	0.9	0.6	0.6	0.8	1.3	0.8	1.0
25	10.6	9.3	4.6	2.6	1.3	0.8	2.0	0.7	0.7	1.2	0.8	0.7

48 HOUR DEPRIVATION GROUP, NON-FORCED

Rat No.	Days				
	1	2	3	4	5
	Average Total-Minus-Choice Running Time in Seconds, Extinction				
1	1.1	2.2	3.4	3.6	3.3
8	1.1	11.5	14.4	26.9	14.6
16	1.1	5.0	18.6	4.8	3.2
21	7.4	2.8	2.7	7.7	4.3
25	2.8	20.6	5.0	4.4	2.9
	Average Choice-Minus-Latency Running Time in Seconds, Extinction				
1	7.9	5.2	2.7	14.9	5.6
8	1.8	6.4	4.2	10.8	47.4
16	4.2	5.4	4.2	50.9	21.9
21	3.5	2.8	3.1	4.9	4.3
25	4.4	11.2	8.3	14.9	46.8
	Average Latency in Seconds, Extinction				
1	11.5	10.0	17.7	8.6	7.0
8	0.6	0.5	0.7	2.8	1.2
16	7.4	4.3	5.3	49.4	47.7
21	1.6	0.8	0.7	1.2	5.5
25	1.1	4.5	2.1	2.1	22.1

AVERAGE LATENCY IN SECONDS, CONDITIONING

Rat No.	Days													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Zero Deprivation Group, Forced													
3	6.5	10.8	4.4	4.8	7.7	2.9	3.9	1.6	2.5	8.2	2.8	12.1	1.0	0.8
4	18.4	33.8	8.6	5.2	4.1	35.3	1.4	5.7	7.6	2.7	5.4	18.0	5.5	3.2
20	48.6	11.4	6.2	4.6	5.6	3.9	1.8	4.8	11.0	1.9	7.0	1.7	5.2	1.4
26	85.8	143.1	18.1	6.5	43.2	2.0	1.8	1.7	1.3	1.3	1.3	1.6	2.2	0.9
29	4.7	5.6	3.4	2.5	3.6	6.3	1.5	3.8	2.0	1.9	3.9	1.1	1.1	2.8
	24 Hour Deprivation Group, Forced													
6	14.7	7.5	1.6	3.7	8.2	3.1	1.8	2.8	1.5	1.9	1.6	2.9		
14	9.7	35.6	4.2	3.8	2.6	1.2	0.8	3.8	0.7	2.1	0.9	0.7		
19	2.4	2.7	1.7	2.7	6.2	5.4	3.5	1.2	0.9	4.3	21.0	1.1		
22	12.2	61.5	12.3	7.2	2.1	22.6	2.4	2.0	1.3	1.4	4.7	1.0		
28	3.4	1.3	2.8	2.5	2.0	4.7	1.0	1.1	0.5	0.5	0.6	0.8		
	48 Hour Deprivation Group, Forced													
5	44.9	38.6	43.9	3.0	4.3	5.0	2.0	0.8	0.6	0.8	1.3	0.7		
7	16.2	11.6	23.6	1.9	1.3	1.0	1.2	0.5	0.6	0.4	0.5	0.5		
13	5.4	9.8	3.4	1.3	2.7	1.5	1.3	1.3	1.2	0.8	0.7	0.9		
24	12.2	4.3	0.6	1.1	1.4	0.6	0.6	0.9	0.7	2.2	0.6	0.6		

AVERAGE LATENCY IN SECONDS, EXTINCTION

Rat No.	Days				
	1	2	3	4	5
	Zero Deprivation Group, Forced				
3	0.7	0.6	0.6	0.6	3.1
4	2.3	0.5	0.4	4.8	11.9
20	0.7	6.9	1.7	0.8	5.6
26	0.9	1.0	0.6	0.9	2.0
29	1.0	0.5	0.8	0.7	3.6
	24 Hour Deprivation Group, Forced				
6	4.4	24.0	14.7	1.5	6.6
14	1.1	4.3	5.0	2.0	25.2
19	15.1	18.3	20.7	1.5	10.9
22	1.3	8.0	12.7	2.3	1.1
28	2.6	1.2	2.2	1.7	0.8
	48 Hour Deprivation Group, Forced				
5	2.7	12.2	1.7	13.3	158.1
7	6.0	11.8	5.5	93.7	156.1
13	1.5	13.5	5.5	Died	---
24	13.1	2.2	0.6	3.9	1.2

ZERO DEPRIVATION GROUP, FORCED

Rat No.	Days													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Average Total-Minus-Choice Running Time in Seconds, Conditioning. Trials 1 and 2													
3	235.0	494.0	208.0	DNC	230.0	DNC	42.8	DNC	DNC	11.0	11.0	10.0	22.0	37.0
4	294.0	80.6	105.0	306.0	391.8	181.3	229.7	64.6	DNC	DNC	127.2	11.5	46.4	16.7
20	98.0	7.9	27.8	8.0	76.9	76.7	8.3	5.8	2.3	6.6	6.8	5.2	3.8	7.5
26	170.0	166.0	138.0	326.0	DNC	38.0	77.5	DNC	20.0	68.0	27.5	28.0	21.0	75.0
29	138.0	156.5	209.5	146.0	301.5	273.0	121.6	30.0	33.5	58.5	7.5	20.0	19.5	7.5
	Average Total-Minus-Choice Running Time in Seconds, Conditioning. Trials 3 and 4													
3	283.0	219.0	59.3	DNC	573.0	DNC	DNC	239.0	DNC	40.0	DNC	7.5	DNC	DNC
4	315.0	47.6	62.0	42.8	340.5	79.8	351.8	DNC	19.0	DNC	50.5	98.0	29.7	2.2
20	345.0	4.4	9.0	53.9	76.3	26.1	12.1	19.3	102.4	19.1	21.0	50.8	6.3	14.4
26	DNC	DNC	DNC	76.0	9.0	48.0	23.0	126.5	DNC	149.0	5.0	20.0	16.0	134.5
29	600.0	112.5	148.0	180.5	303.0	31.5	38.0	68.5	5.0	5.5	5.5	3.5	1.5	7.0
	Average Choice-Minus-Latency Running Time in Seconds, Conditioning, Trials 1 and 2													
3	223.8	317.8	311.0	600.0	392.8	600.0	217.2	600.0	600.0	310.3	168.5	336.8	308.9	404.0
4	70.2	144.0	147.9	126.8	177.5	395.3	102.4	197.4	600.0	600.0	248.0	212.5	62.3	51.8
20	233.4	211.8	183.9	92.5	79.5	89.0	73.0	74.0	175.0	37.5	24.0	19.5	27.5	18.5
26	129.5	340.0	184.0	313.3	600.0	463.5	273.5	600.0	320.5	135.0	113.0	160.5	24.5	431.0
29	12.0	18.0	32.0	11.0	8.6	57.0	20.0	45.0	17.5	15.0	6.5	15.0	12.0	6.0
	Average Choice-Minus-Latency Running Time in Seconds, Conditioning. Trials 3 and 4													
3	458.6	311.4	287.2	600.0	313.5	600.0	600.0	136.1	600.0	149.6	600.0	508.8	600.0	600.0
4	202.7	413.7	55.7	154.1	205.5	557.6	154.1	600.0	495.1	600.0	312.3	154.3	19.7	63.5
20	328.4	354.2	470.5	114.0	326.0	100.0	36.0	56.0	147.0	8.0	60.5	38.0	34.5	33.0
26	600.0	600.0	600.0	302.5	307.0	333.5	356.0	159.5	600.0	525.0	317.5	250.5	34.5	138.0
29	15.5	68.5	30.5	8.5	14.0	35.5	18.5	15.0	6.0	3.0	14.0	2.0	2.0	3.5

ZERO DEPRIVATION GROUP, FORCED

Rat No.	Days 1	2	3	4	5
	Average Total-Minus-Choice Running Time, Extinction, Trials 1 & 2				
3	2.9	DNC	DNC	49.2	6.4
4	23.1	6.6	26.4	9.5	7.2
20	7.8	7.2	8.6	3.4	20.8
26	10.0	25.0	38.0	4.0	40.0
29	10.5	4.5	5.5	42.5	14.5
	Average Total-Minus-Choice Running Time in Seconds, Ext., Trials 3&4				
3	DNC	DNC	238.0	DNC	126.0
4	42.1	3.4	2.6	189.4	2.9
20	6.1	2.0	5.6	24.6	6.9
26	13.0	46.5	162.5	35.0	12.0
29	3.5	1.5	1.0	29.0	10.0
	Average Choice-Minus-Latency Running Time in Seconds, Ext., Trials 1 & 2				
3	306.8	600.0	600.0	439.4	330.0
4	342.1	119.0	13.0	46.7	147.2
20	27.5	34.0	34.0	20.5	32.0
26	316.5	305.5	123.0	439.0	302.0
29	12.5	10.0	15.5	8.5	14.5
	Average Choice-Minus-Latency Running Time in Seconds, Ext., Trials 3 & 4				
3	600.0	600.0	302.8	600.0	364.1
4	35.6	1.6	3.6	315.1	331.2
20	166.0	10.5	38.0	156.5	21.5
26	27.0	125.0	11.5	341.0	338.0
29	1.5	1.5	1.5	2.0	1.5

24 HOUR DEPRIVATION GROUP, FORCED

Rat No.	Days											
	1	2	3	4	5	6	7	8	9	10	11	12
	Average Total-Minus-Choice Running Time in Seconds, Conditioning, Trials 1 & 2											
6	19.0	10.5	3.5	5.0	2.5	1.5	2.0	0.9	1.0	1.2	1.4	1.6
14	15.2	5.5	2.8	1.2	1.4	0.9	1.3	1.2	1.2	1.0	1.0	1.1
19	35.8	6.0	2.6	7.6	8.4	4.5	2.0	1.3	0.8	1.0	1.0	1.1
22	18.0	5.6	3.5	2.4	1.6	1.6	2.1	1.7	1.2	1.2	3.7	1.8
28	17.0	4.8	6.0	7.4	18.8	1.9	7.7	2.0	11.1	2.3	3.4	3.2
	Average Total-Minus-Choice Running Time in Seconds, Conditioning, Trials 3 & 4											
6	42.0	11.0	10.5	3.0	4.0	1.5	11.0	12.5	6.4	10.8	29.2	11.6
14	16.5	5.6	3.0	1.7	1.7	2.2	4.0	3.3	3.3	6.8	4.0	2.6
19	17.2	4.3	22.6	19.2	57.2	39.3	28.9	5.6	5.4	16.8	73.8	49.9
22	15.8	10.9	2.6	6.9	7.0	25.8	19.6	12.4	16.8	17.6	64.0	7.5
28	24.2	4.6	4.9	3.0	2.0	5.2	4.3	13.5	7.4	30.4	5.1	149.0
	Average Choice-Minus-Latency Running Time in Seconds, Conditioning, Trials 1 & 2											
6	25.0	62.5	36.5	18.5	16.5	5.0	5.0	3.0	3.5	3.5	5.0	4.5
14	42.7	47.9	10.4	3.2	6.5	2.4	2.8	2.9	2.4	2.6	3.1	2.6
19	17.4	8.3	12.4	54.3	13.9	39.4	6.4	8.4	3.6	2.9	5.5	3.7
22	8.3	6.6	23.8	26.3	11.2	5.4	4.8	4.2	2.8	2.4	3.4	7.3
28	19.5	10.9	13.4	25.5	17.8	4.2	14.8	5.9	9.0	6.4	3.4	4.5
	Average Choice-Minus-Latency Running Time in Seconds, Conditioning, Trials 3 & 4											
6	50.0	25.5	35.0	14.5	38.5	48.0	4.5	14.0	45.5	80.5	23.5	47.5
14	96.6	35.0	15.7	6.9	7.4	7.0	5.2	12.5	6.8	55.8	11.1	4.4
19	5.6	5.4	25.2	46.8	98.4	83.4	17.4	17.8	29.3	179.9	38.5	91.2
22	38.5	115.0	5.0	112.4	7.2	33.4	42.4	57.0	40.2	10.6	127.2	25.4
29	11.9	21.2	18.5	10.4	23.1	8.1	47.3	10.5	7.2	7.4	20.2	26.6

24 HOUR DEPRIVATION GROUP, FORCED

Rat No.	Days				
	1	2	3	4	5
	Average Total-Minus-Choice Running Time in Seconds, Ext., Trials 1 & 2				
6	5.4	5.0	13.4	5.6	43.9
14	2.4	4.4	19.4	2.2	7.2
19	4.2	4.0	16.6	1.4	37.9
22	8.8	1.3	9.6	23.5	75.2
28	7.0	10.6	33.7	24.3	10.6
	Average Total-Minus-Choice Running Time in Seconds, Ext., Trials 3 & 4				
6	19.6	69.8	14.3	27.6	4.8
14	8.2	8.6	20.3	36.4	31.1
19	47.0	36.6	7.5	10.0	1.3
22	21.9	22.3	29.8	13.2	3.8
28	11.2	23.3	6.6	101.0	26.9
	Average Choice-Minus-Latency Running Time in Seconds, Ext., Trials 1 & 2				
6	7.5	29.5	25.0	13.0	11.5
14	3.8	22.2	17.5	4.7	11.4
19	7.9	32.6	51.4	4.3	96.4
22	23.4	313.4	13.6	29.4	19.6
28	9.9	8.9	20.8	4.8	10.6
	Average Choice-Minus-Latency Running Time in Seconds, Ext., Trials 3 & 4				
6	4.0	17.5	6.5	6.0	2.0
14	4.6	11.0	5.0	3.2	6.4
19	9.8	61.4	6.7	21.3	5.4
22	58.4	51.9	133.1	11.9	14.7
28	13.6	3.8	29.0	34.1	27.8

48 HOUR DEPRIVATION GROUP, FORCED

Rat No.	Days											
	1	2	3	4	5	6	7	8	9	10	11	12
	Average Total-Minus-Choice Running Time in Seconds, Conditioning, Trials 1 & 2											
5	24.0	3.9	2.9	1.9	1.7	1.8	2.0	1.3	1.4	1.2	1.4	1.2
7	16.6	5.2	3.8	1.6	1.3	1.0	1.4	1.6	1.2	2.0	1.0	0.8
13	8.8	6.6	2.2	1.3	1.2	1.0	1.6	1.6	1.5	1.6	1.0	1.1
24	19.2	11.7	5.0	1.7	1.2	1.1	1.8	0.8	1.2	1.2	1.0	1.4
	Average Total-Minus-Choice Running Time in Seconds, Conditioning, Trials 3 & 4											
5	16.1	4.2	2.2	2.0	2.3	4.6	1.6	2.7	2.7	2.9	0.8	5.0
7	6.7	4.8	2.7	2.3	13.4	2.0	1.6	5.1	2.0	6.6	1.4	7.0
13	4.0	4.7	17.6	2.0	8.4	11.2	8.6	5.2	33.2	4.6	4.7	4.3
24	7.4	3.6	1.4	1.6	3.5	1.2	9.2	1.8	4.7	2.3	3.3	7.8
	Average Choice-Minus-Latency Running Time in Seconds, Conditioning, Trials 1 & 2											
5	45.8	40.4	6.0	5.4	3.0	4.5	3.3	3.0	2.3	2.2	2.4	3.8
7	17.4	7.4	7.0	2.3	2.4	2.0	2.0	2.4	1.8	1.4	1.8	1.5
13	10.6	6.7	5.2	2.0	2.8	2.3	2.2	3.2	2.6	1.9	1.9	3.0
24	10.6	11.6	4.1	1.1	2.2	2.8	4.5	1.6	1.7	2.6	2.0	3.7
	Average Choice-Minus-Latency Running Time in Seconds, Conditioning, Trials 3 & 4											
5	22.1	40.9	4.3	3.9	7.4	4.8	5.0	2.8	5.9	4.1	3.0	7.8
7	9.9	9.6	12.3	24.8	4.6	27.2	9.9	2.3	9.4	2.8	11.6	2.8
13	12.4	8.0	8.8	22.0	47.4	6.2	18.8	14.2	5.0	10.8	12.8	7.8
24	68.2	4.6	6.2	4.4	6.2	5.8	5.4	42.1	86.8	2.8	20.6	15.0

48 HOUR DEPRIVATION GROUP, FORCED

Rat No.	Days				
	1	2	3	4	5
	Average Total-Minus-Choice Running Time in Seconds, Ext., Trials 1 & 2				
5	1.1	2.8	6.6	4.2	DNC
7	2.8	7.4	11.6	16.2	DNC
13	0.9	8.7	8.9	Died	---
24	0.9	2.6	6.1	18.6	2.4
	Average Total-Minus-Choice Running Time in Seconds, Ext., Trials 3 & 4				
5	2.8	2.0	1.8	10.6	6.3
7	5.2	1.7	3.6	DNC	DNC
13	2.8	3.0	1.9	Died	---
24	4.4	18.2	1.2	11.2	2.4
	Average Choice-Minus-Latency Running Time in Seconds, Ext., Trials 1 & 2				
5	2.6	5.7	6.2	15.5	600.0
7	1.4	5.4	4.6	333.2	600.0
13	2.8	9.4	6.6	Died	---
24	2.0	6.4	4.4	5.8	9.0
	Average Choice-Minus-Latency Running Time in Seconds, Ext., Trials 3 & 4				
5	8.8	6.3	5.4	101.6	343.3
7	2.0	4.2	5.0	600.0	600.0
13	3.2	7.1	9.9	Died	---
24	5.6	3.1	2.0	174.2	10.3